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St. Vincent Cancer Center: construction Management through 5D Building Information Modeling with Alternative Floor System Designs

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St. Vincent Cancer Center: Construction Management through 5D Building Information Modeling with Alternative Floor System Designs

A Major Qualifying Project

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Abstract

St. Vincent Hospital is currently building a Cancer Center in the Worcester City Square development to meet growing needs of cancer research and treatment. This report examined alternative structural floor systems for this building that may result in faster construction and lower the cost of the project. Building Information Modeling software was utilized to assist in the investigation. The investigation proved that the existing design is the most effective approach for the construction of St. Vincent Cancer Center.

Authorship

The following list indicates the primary areas of focus in the report for each member of the team:

John Dias –Building Separation Joint, Precast Concrete Design, Evaluations

Kevin Griffin – 3D *Revit* Models, *Robot* Model Analyses, 5D *Navisworks* Model, Cost Estimates, Evaluations

Shaine Grogan – Baseline Analysis, Open-Web Bar Joists Design, Precast Concrete Design, *Robot* Model Analyses, Evaluations

Greg Mollnow – Cost Estimates, *Primavera* Schedules, Evaluations

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Capstone Design Statement

When construction is completed in spring of 2013, St. Vincent Cancer Center located in the new City Square Development will be a state-of-the-art facility that will have a positive impact on cancer patients in the Worcester area. Throughout the construction of this facility many obstacles have been addressed. Our Major Qualifying Project consisted of reviewing the existing floor system design and exploring two alternative floor system designs under the design loads for St. Vincent Cancer Center. This study also determined the effects of these alternative designs on their corresponding cost and scheduling. Building Information Modeling (BIM), Autodesk *Robot* and Autodesk *Revit*, as well as *Primavera* scheduling software were used to aid in the design and constructability analysis process.

The following realistic constraints were addressed during the completion of this project: economic, environmental, constructability, health and safety, and social.

The economic impact of the alternative floor system designs is the first constraint. A structural analysis was performed, along with a cost and construction schedule impact examination, to determine the most effective new floor system that can support the required design loads of the facility. This was completed with aid from *Primavera*, Autodesk *Revit*, and Autodesk *Robot*. Once data was received from these software programs, the design options were compared against each other to determine the most effective floor system for the Cancer Center.

The next constraint, constructability of the alternative designs, is very similar to the economic constraint. This constraint was met by researching the structural design of alternative floor systems. These proposed alternatives made use of standard section and repetitive elements to make them feasible alternatives. We determined if the constructability of these alternative designs will affect the cost and schedule of the project

The environmental constraint was met through exploring local environment variables during construction. We examined such effects, such as traffic disruption, that the St. Vincent Cancer Center project has on the surrounding City Square Development and traffic in Worcester.

The health and safety constraint was met by determining that the alternative design sustained the required design loads of the facility. We ensured the designs met the appropriate provisions of the *Massachusetts State Building Code* with *ASCE 7* to complete the structural designs. Finally, we will also research safety factors that will occur during the construction phase.

The final constraint explored was the social constraint. This constraint was addressed throughout the duration of our project because the Cancer Center has a large impact on the community. Many patients in the Worcester area will be using this center for treatments. While creating alternative designs for the Cancer Center, we designed our systems within certain codes. These codes help to ensure that the structure will be suitable for daily use by the patients.

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1.0 Introduction

Older cities are being redeveloped to allow for new construction in crowded areas. Outdated buildings must either be retrofitted or torn down to make way for new facilities. This is especially true for the health and safety of society and the expansion of medical facilities. Expansion is needed due to the growth in technology and the always advancing world of medicine and to make room for more patients, research space, treatment areas, etc. This is also true when it comes to cancer because of the disease's rapid growth and fatality rate. With the increasing needs for these facilities, the construction industry is called upon to carry out these projects. (St. Vincent Hospital, 2012).

Worcester, MA is in need of such a facility, but lacks the space around the metropolitan area. Located in the heart of Worcester, St. Vincent Hospital is now expanding its cancer research and treatment in the new urban development in Worcester, called City Square, which is currently being constructed adjacent to the main campus of St. Vincent Hospital. As with all construction, St. Vincent Hospital has limited funds for an expansion, and needs the most cost and time effective plan of construction that will suit their needs (St. Vincent Hospital, 2012)..

Among other functions, this development will provide the essential space needed (approx. 66,000 sq. ft.) for St. Vincent expansion. The St. Vincent Cancer Center consists of three floors for both cancer treatment and office space. The medical care space consists of a radiation area for state-of-the-art equipment, waiting, exam, and recovery rooms for patients before and after procedures and office space for the medical staff of the facility.

The construction of medical buildings can be a very challenging process. There are many decisions to be made during the design of a structure, which can greatly affect the budget and timeline of construction. This includes meeting the needs of the community the building will serve and the needs of the doctors that will be working in the facility. Space within the City Square development is limited therefore the Cancer Center is currently built within two feet of an existing parking garage. Expansion joints are commonly used to mitigate the effects of movement between buildings and must be evaluated to determine the effects these have on the construction of the building. Many disciplines contribute to a project, including the architect, construction manager, engineers, subcontractors, and owner. These disciplines must work together to produce a costly, timely and structurally efficient solution for the owner.

The current structural design of the building consists of steel frame with elevated concrete slabs on steel decking. This study investigated two alternative designs to the floor system of the St. Vincent Cancer Center. The two alternative designs are compared with the existing design to recommend the most cost and time effective option. The design evaluations were performed from the perspectives of constructability and cost efficiency. The first alternative design proposes the use of open-web bar joists in place of I-beams as designed in the current the steel structure. The second alternative examines precast concrete planks to replace the cast-in-place concrete floor system. Using Building Information Modeling (BIM) models were created through *Autodesk Revit software* to visualize each alternative design. The models have been exported from *REVIT* and imported into *Autodesk* R*obot software* for further structural analysis to ensure that the designs are structurally sound. A cost-estimate and a schedule of activities for each design have been prepared. The elements of cost and time were combined with a 3D structure to make a 5D model. A 5D model helps to create a clear and complete overview and understanding of the design and cost-time implications of the project, with real-time simulation and visualization of the structure.

The goal of this project was to determine an alternative floor system that met the structural needs of the building as well as prove more cost and time effective than the existing design. The model that has the most benefits will be the floor system we suggest for construction.

2.0 Background

This background chapter examines the growing need for a Cancer Center at St. Vincent Hospital Worcester, MA. The section starts with a discussion of St. Vincent Hospital and the development of City Square. Following sections provide an overview of project management and structural designs. In several of these sections the application of computer software and Building Information Modeling in construction processes is discussed.

2.1 The History of City Square

On July 29th, 1971, the city of Worcester, Massachusetts officially became the home of the brand new 1,000,000 square foot Worcester Center Galleria (Huard, 2012). Attached to the Galleria, a 4,300-car parking structure was constructed with the anticipation of a large popularity for the new city development. At that time, that parking structure was the largest parking structure in the world (Huard, 2012). Figure 1 shows an aerial photograph taken of the Worcester Center Galleria parking structure.

Figure 1: Worcester Center Galleria parking structure (Telegram & Gazette, 1971).

Despite being one of the largest shopping retail venues in Worcester, the popularity of the new Galleria did not live up to expectations (Huard, 2012). Other local competitors and vendors gained the business of customers. The Galleria went through numerous name changes to go along with multiple remarketing efforts. However, the fate of the mall took a turn for the worse with the opening of the nearby Wrentham Village Premium Outlets in 1997 (Huard, 2012). After nine more years of struggling to keep tenants, the Galleria, which in past years was renamed the Worcester Common Outlets, was closed in 2006. Upon the mall's closing, property owner Berkeley Investments put together a redevelopment plan for a pedestrian friendly, mixed use development called City Square.

2.2 The Future of City Square

The development of City Square has been a project that most Worcester residents would consider long overdue in light of the failure of the existing shopping mall. Partners Opus Investments, Hanover Insurance Group (the real estate arm), and Leggat McCall will be providing substantial financial assets, overall project scope, and most of all, hope for the run down area of Worcester (City of Worcester, 2012). With removal of the existing mall and parking structure, the 20 plus acres will be the new home of upscale urban residences, restaurants, clubs, retails shops, entertainment venues, and state of the art medical, life sciences, and professional office space. When construction of the new Square is completed in summer of 2013, it is expected to have a cost of approximately $563 million dollars making the Worcester City Square project the largest public/private development project in Massachusetts history with the exception of the City of Boston.

The first phase of the project includes the construction of the 214,000 square foot Unum Building, and the 66,000 square foot Saint Vincent Cancer Center (City of Worcester, 2012). The

Unum project is primarily funded by the Unum Group, and construction is expected to be approved for LEED-Silver certification. The Unum Group expects for the building to be occupied by January 2013. Saint Vincent Hospital will invest $21 million, and the expected date of completion is the spring of 2013. Early construction phases in 2011, of Saint Vincent Cancer Center can be seen in Figure 2.

Figure 2: Saint Vincent Cancer Center in Early Construction Phases. (City of Worcester, 2012)

2.3 St. Vincent Hospital

Saint Vincent Hospital was originally founded by the Sisters of Providence in 1893. At first, the hospital was a Catholic community-based hospital and was named after the patron saint of the Sisters' order, Saint Vincent de Paul (St. Vincent Hospital, 2012). Pictured in Figure 3, the hospital, located on Vernon Hill in Worcester, contained twelve beds and had a capacity to care for a total of 30 patients.

Figure 3: Saint Vincent Hospital in 1893 (St. Vincent Hospital, 2012)

After moving to various to new locations and settling into larger facilities, Saint Vincent opened a nursing school in 1900 (St. Vincent Hospital, 2012). A larger facility was constructed on Providence Street, Worcester, in 1922 strictly for the nursing school. The school had great success but closed in May of 1988. More building expansions occurred in: 1964 with a five story service wing, 1965 with the Bishop Wright Pavilion (containing a 51-bed psychiatric ward, 45-bed maternity section, and 52-bed surgical floor), 1969 the Anderson Building (housing the Data Processing Center), 1970 the Rose Building built for laboratory and research, and 1984 with the amphitheater and modern medical library.

In 1990, Saint Vincent Healthcare System formed after the hospital was corporately recognized in 1983 (St. Vincent Hospital, 2012). At this time, the hospital merged with Fallon Healthcare System, creating the first vertical integrated healthcare facility, which offers a broad range of patient care and support services, in the Worcester area. In recent years, the current hospital was renamed Worcester Medical Center. In 1997, construction of the Worcester Medical Center commenced and was completed on April 1, 2000. A rendition of the completed project is in 1990, Saint Vincent Healthcare System formed after the hospital was corporately recognized in 1983 (St. Vincent Hospital, 2012). At this time, the hospital merged with Fallon Healthcare System, creating the first vertical integrated healthcare facility, which offers a broad range of patient care and support services, in the Worcester area. In recent years, the current hospital was renamed Worcester Medical Center. In 1997, construction of the Worcester Medical Center commenced and was completed on April 1, 2000. A rendition of the completed project is shown in Figure 4. Vanguard Health System purchased the state-of-the-art facility in 2005 and continues to uphold the Catholic foundation in which the hospital was first built.

Figure 4: St. Vincent Medical Center (St. Vincent Hospital, 2012)

2.4 Project Management

Design-Build (D-B) projects are becoming a more common form of construction. This method allows the owner to hire a single entity for design and construction and to help the project move along faster, because the construction of the project can begin before the structure is fully designed. This method is selected when the schedule is most important, cost is secondary, and the scope is not entirely defined (Oberlender, 2000). Although in D-B projects a firm is generally hired to design and then manage the construction of the project, with this project

Gilbane (a construction management firm) has been hired by St. Vincent Hospital to lead the Design-Build entity and subcontract the design, as well as to manage the project. Gilbane was hired in early April of 2009 to begin pre-construction on this project. Symmes, Maini, & Mckee Assoc. was hired as the designer by Gilbane for this project.

2.4.1 Organizational Breakdown

The St. Vincent Cancer Center project is a design-build project. This usually means that owner hires a design-build firm to coordinate the design and construction of the project (Oberlender, 2000). Fast-tracking is a method used when the full design of the project is not complete, but construction can begin; future parts of the project can be designed and adjusted accordingly based on how the initial construction phases go. Fast-tracking has the advantage of a reduced completion time, which will save the owner time and reduce construction costs. The owner often has more control over design revisions while construction is underway because the design is still being adjusted for finish phases. There are several contractual arrangements for financial compensation to the construction management firm. Many times, a cost reimbursable contract is used because the scope is not well-defined and an accurate budget cannot be estimated. In other cases, including the St. Vincent Cancer Center, there is a well-defined scope, and a guaranteed maximum price contract (GMP) can be used. Figure 5 shows the contractual arrangement and organizational breakdown for the St. Vincent project.

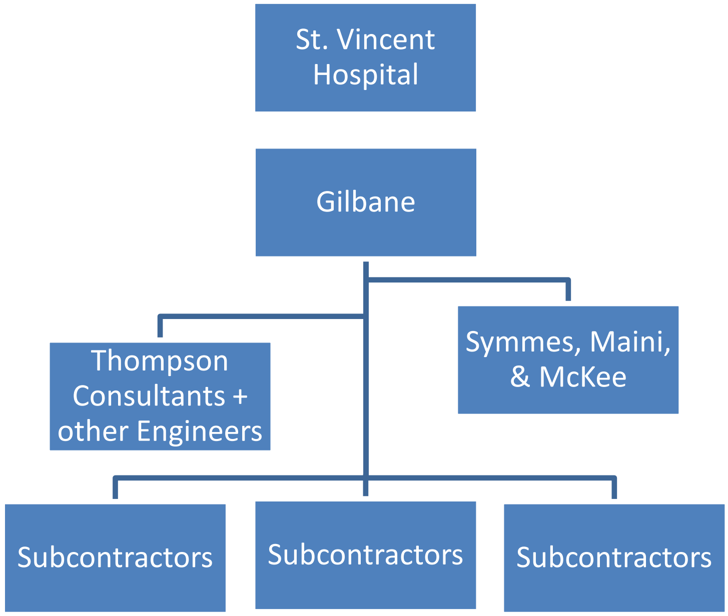


Figure 5: Organizational Breakdown for St. Vincent Cancer Center

The owner of the project is St. Vincent Hospital. Gilbane leads the design-build entity for the job. Working on the design team are Symmes, Maini, & McKee Associates and Thompson Consultants, among other engineers. There are eighteen subcontractors on the job, including JL Marshall & Sons, Inc. for concrete and United Steel for steel. A complete list of subcontractors and engineers can be found in Appendix B (Gilbane, 2012).

2.4.2 Cost

This project is a contractor led design-build. This means that they will take the lead and work to finish the project in the best interest of the owner. The owner selected a Contractor (Gilbane) to lead this process. From here, based on SMMA design, Gilbane created bid packages with individual scopes of work for different subcontractors. With these packages completed, drawings and contract documents were sent to different subcontractors to bid on the job. Once the subcontractors were awarded the contracts, the actual cost of the project can be determined. Due to complexity of projects, the actual cost cannot be determined for months. In order to get the project off the ground most of these subcontractors must be awarded early, but other non-critical activities can be awarded later in the process.

The Cancer Center is a Guaranteed Maximum Price (GMP) contract. This means the Design-Builder agreed to a fixed completion date and a maximum price for the project. In order to ensure project completion by the fixed date, the owner will have liquidated damages in the contract. Liquidated damages are a penalty that the CM must pay every day the project exceeds agreed upon date. The GMP can be set before or after subcontractor bids, but waiting to receive bids makes a more accurate GMP. This gives a more accurate price and a smaller chance for change orders. The GMP for the Cancer Center is $14,220,858 (Gilbane, 2012).

2.4.3 Schedule

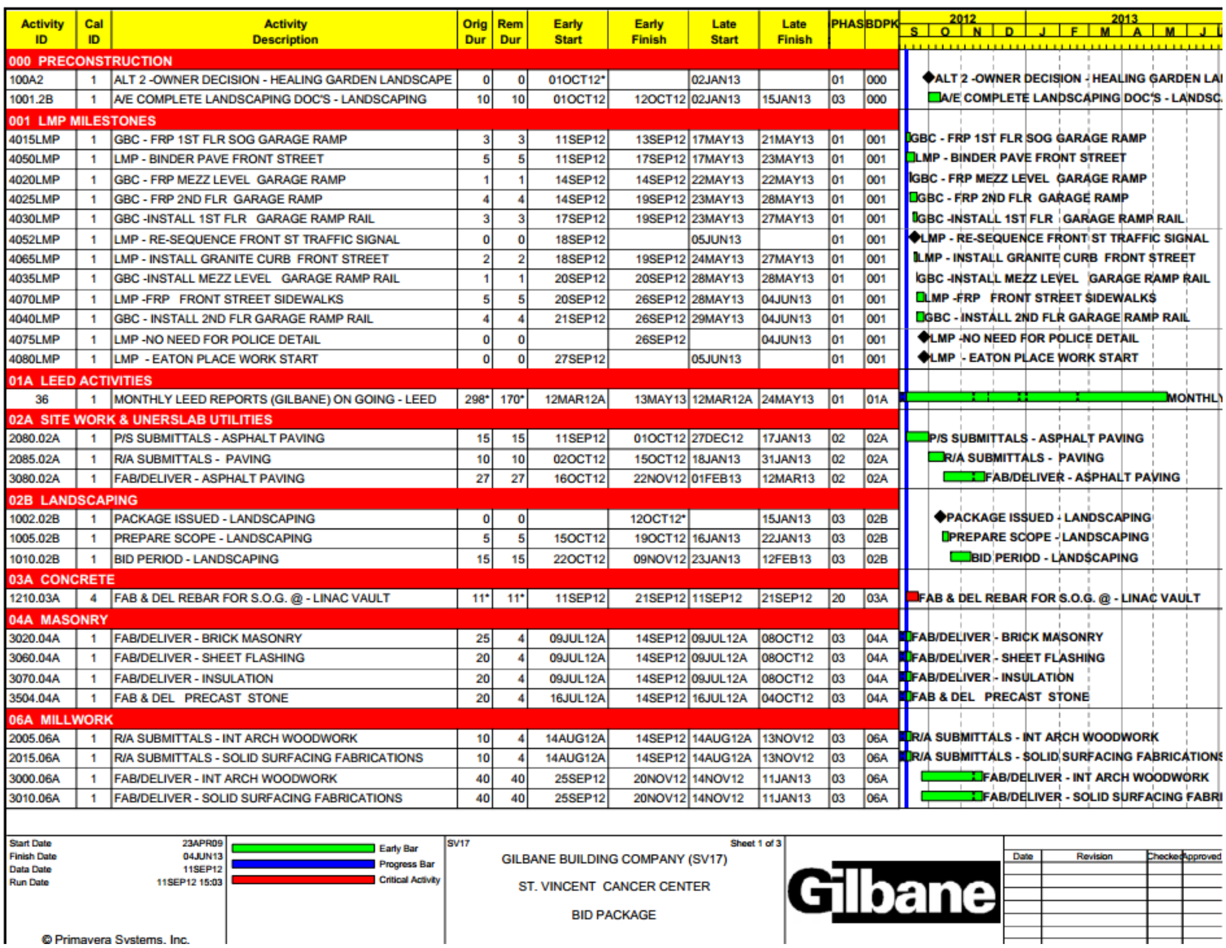
To complete this project on time Gilbane has set milestones and assigned a scheduler to this project. The job of the scheduler is to create a well thought out schedule that allows for the completion of the project in an agreed upon time to satisfy the owner. If any conflicts come up during construction, it is the job of the scheduler and the project manager to figure out how to make amends to the schedule to finish on time. Milestones are necessary activities used to judge the progress of the project. In order to maintain the schedule the project must meet these milestones. Construction on this project is scheduled to start on April 23, 2012 and end on May 27, 2013 (Gilbane).

Along with the schedule, site accessibility, storage space, and the overall size of the lot the project is on play a big role in finishing a project on time. This project is taking place in a small area with Consigli completing a construction project on an adjacent site. Due to this, Gilbane must use parts of Consigli's site in order to facilitate the project. Gilbane can only use this land as a drop off location, but not a storage location, which poses another problem to their construction progress. This means that Gilbane must use a drop-off and install type of construction as they do not have much storage space for construction materials. The site is set-up with two cranes, one at the north end of the project, and the other on the west side of the site, that can be used to reach all parts of the project. These features of the site must all work in accordance with each other and the schedule in order to finish the project.

Time and cost are two of the most scrutinized factors of a construction process. One goal of every project is to be completed by or before the agreed upon date, which in turn can help a project stay within budget. The most effective way to stay on track and meet time requirements is to create a schedule. While there are many computer programs available to do this, *Primavera* goes above and beyond generating a simple timeline (Oracle, 2010).The program allows the user to add as little or as much information to produce a simple or complex multilevel schedule. Large construction companies, such as Gilbane, usually have a multitude of projects happening at the same time. Software like *Primavera* helps create a breakdown of the project on different levels so different parts of a firm can examine what they need. This can be jobs to complete milestones for upper management, to a task by task daily schedule for employees in the field (Primavera, 2007).

Primavera is a software program that is most commonly used to create a schedule. This program has the capabilities to track all of the important aspects of a schedule, such as duration of activities, cost, and relationships between activities. *Primavera* can be used to track contracts, risk management, and document control items. This is done through integration with other programs like E-Business and JD Edwards Enterprise One (Oracle, 2011a). It can track contract summary to date, change orders, and payment processing rates. For risk management, the program can calculate confidence levels based upon common pitfalls that are associated with activities in the schedule and risk factors that are predefined in the program. Pertaining to document control, the program allows the monitoring of communication processes such as number of resolved and unresolved issues, actions that must be taken to keep the track on schedule, and RFI and submittal turnaround rates (Oracle, 2011b).

Primavera is Construction Project Management software that can be used to order tasks of the project. This means that the program allows the user to set an order of precedence in order to manage the critical path of the project. The critical path method (CPM) is generally implemented in many construction schedules. This method sets chains of activities with no float time in order, which is done to accurately determine the end date of the project. If these activities are not completed on time, then the completion date of the project will be pushed back.



Activity ID	Cal ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Late Start	Late Finish	PHAS	BDPK
000 PRECONSTRUCTION										
100A2	1	ALT 2 -OWNER DECISION - HEALING GARDEN LANDSCAPE	0	0	01OCT12*		02JAN13		01	000
1001.2B	1	A/E COMPLETE LANDSCAPING DOC'S - LANDSCAPING	10	10	01OCT12	12OCT12	02JAN13	15JAN13	03	000
001 LMP MILESTONES										
4015LMP	1	GBC - FRP 1ST FLR SOG GARAGE RAMP	3	3	11SEP12	13SEP12	17MAY13	21MAY13	01	001
4050LMP	1	LMP - BINDER PAVE FRONT STREET	5	5	11SEP12	17SEP12	17MAY13	23MAY13	01	001
4020LMP	1	GBC - FRP MEZZ LEVEL GARAGE RAMP	1	1	14SEP12	14SEP12	22MAY13	22MAY13	01	001
4025LMP	1	GBC - FRP 2ND FLR GARAGE RAMP	4	4	14SEP12	19SEP12	23MAY13	28MAY13	01	001
4030LMP	1	GBC -INSTALL 1ST FLR GARAGE RAMP RAIL	3	3	17SEP12	19SEP12	23MAY13	27MAY13	01	001
4052LMP	1	LMP - RE-SEQUENCE FRONT ST TRAFFIC SIGNAL	0	0	18SEP12		05JUN13		01	001
4065LMP	1	LMP - INSTALL GRANITE CURB FRONT STREET	2	2	18SEP12	19SEP12	24MAY13	27MAY13	01	001
4035LMP	1	GBC -INSTALL MEZZ LEVEL GARAGE RAMP RAIL	1	1	20SEP12	20SEP12	28MAY13	28MAY13	01	001
4070LMP	1	LMP -FRP FRONT STREET SIDEWALKS	5	5	20SEP12	26SEP12	28MAY13	04JUN13	01	001
4040LMP	1	GBC - INSTALL 2ND FLR GARAGE RAMP RAIL	4	4	21SEP12	26SEP12	29MAY13	04JUN13	01	001
4075LMP	1	LMP -NO NEED FOR POLICE DETAIL	0	0		26SEP12		04JUN13	01	001
4080LMP	1	LMP - EATON PLACE WORK START	0	0	27SEP12		05JUN13		01	001
01A LEED ACTIVITIES										
36	1	MONTHLY LEED REPORTS (GILBANE) ON GOING - LEED	298*	170*	12MAR12A	13MAY13	12MAR12A	24MAY13	01	01A
02A SITE WORK & UNERSLAB UTILITIES										
2080.02A	1	P/S SUBMITTALS - ASPHALT PAVING	15	15	11SEP12	01OCT12	27DEC12	17JAN13	02	02A
2085.02A	1	R/A SUBMITTALS - PAVING	10	10	02OCT12	15OCT12	18JAN13	31JAN13	02	02A
3080.02A	1	FAB/DELIVER - ASPHALT PAVING	27	27	16OCT12	22NOV12	01FEB13	12MAR13	02	02A
02B LANDSCAPING										
1002.02B	1	PACKAGE ISSUED - LANDSCAPING	0	0		12OCT12*		15JAN13	03	02B
1005.02B	1	PREPARE SCOPE - LANDSCAPING	5	5	15OCT12	19OCT12	16JAN13	22JAN13	03	02B
1010.02B	1	BID PERIOD - LANDSCAPING	15	15	22OCT12	09NOV12	23JAN13	12FEB13	03	02B
03A CONCRETE										
1210.03A	4	FAB & DEL REBAR FOR S.O.G. @ - LINAC VAULT	11*	11*	11SEP12	21SEP12	11SEP12	21SEP12	20	03A
04A MASONRY										
3020.04A	1	FAB/DELIVER - BRICK MASONRY	25	4	09JUL12A	14SEP12	09JUL12A	08OCT12	03	04A
3060.04A	1	FAB/DELIVER - SHEET FLASHING	20	4	09JUL12A	14SEP12	09JUL12A	08OCT12	03	04A
3070.04A	1	FAB/DELIVER - INSULATION	20	4	09JUL12A	14SEP12	09JUL12A	08OCT12	03	04A
3504.04A	1	FAB & DEL PRECAST STONE	20	4	16JUL12A	14SEP12	16JUL12A	04OCT12	03	04A
06A MILLWORK										
2005.06A	1	R/A SUBMITTALS - INT ARCH WOODWORK	10	4	14AUG12A	14SEP12	14AUG12A	13NOV12	03	06A
2015.06A	1	R/A SUBMITTALS - SOLID SURFACING FABRICATIONS	10	4	14AUG12A	14SEP12	14AUG12A	13NOV12	03	06A
3000.06A	1	FAB/DELIVER - INT ARCH WOODWORK	40	40	25SEP12	20NOV12	14NOV12	11JAN13	03	06A
3010.06A	1	FAB/DELIVER - SOLID SURFACING FABRICATIONS	40	40	25SEP12	20NOV12	14NOV12	11JAN13	03	06A

Figure 6: Primavera Schedule for Cancer Center (Gilbane, 2012)

Pictured above in Figure 6, is an example of a *Primavera* schedule (Gilbane, 2012). The schedule is generally broken down into different groups based on the trade, level of building, phase of construction, etc. Figure 6 is a schedule from Gilbane broken down by trade for the St. Vincent Cancer Center. The columns on the left contain the activities along with each activity's original duration, remaining duration, early start, early finish, late start, late finish, phase, and bid package. The durations, starts, and finishes are the most important and are what define the schedule's timeline. Any delays or time gains can be recorded and used to move tasks around on the fly. Another key feature is assigning activities to follow other specific activities, which are called successors. For example, the concrete floor slabs cannot be placed until the metal decking is ready, so if the metal deck is laid early and recorded in *Primavera*, the program will show that the concrete can be placed early. The right side of the schedule uses a bar chart to show the progression of the project, with the vertical blue line representing the current day.

Float is another important aspect of a schedule (Oberlender, 2000). There are two different types of float: total float and free float. Total float is the number of days one activity can be delayed and there will be no effect on the final completion date of the project. Free float is the number of days a single activity can be delayed that would not affect the earliest start time of the next activity in the schedule. It is important to monitor and calculate both of these floats, especially total float, to complete the project on time. If total float is exceeded, the activity has the potential to become a critical activity and affect the completion time of the project. Schedules can also display relationships that are established between the activities

A final aspect that makes a schedule a valuable tool for construction management is the capability to aid in the computation of Earned Value Analysis (EVA) of a project (Oberlender, 2000).. EVA is a comparison of the cost of the projected work up to a certain point and the actual cost of work that has been completed. This analysis can be used to determine if the cost, schedule, and work accomplished are progressing in accordance with the plan. With an up-to-date schedule, the quantity of work completed can be determined and compared to previously projected work. This analysis is used to evaluate both cost and schedule. Gilbane tracks the manpower to assess the progress of the project instead of the Earned Value Analysis as a type of project control.

2.4.4 Building Information Modeling (BIM) in Project Management

Building Information Modeling, or BIM, has revolutionized the construction industry by allowing firms to "simulate project's many phases or individual components, thus minimizing the chances for error and reducing the cost of a project" (O'Brien, 2010). The basics of BIM revolve around 3D modeling software, such as *Autodesk Revit*, but this is only the first of many pieces. Large amounts of building information from all parts of a project can be coordinated into the model to visually display relationships with other portions of the project (Smith, 2009). The architect can create the initial building model. The structural engineer can add in structural members. The civil engineer can use GPS coordinates and other terrain tools to show the building in its exact geological location. The electrical, plumbing, and HVAC subcontractors can add light fixtures, pipes, and ductwork to create specific systems. Different programs can take each piece of the model and look for errors and clashes; further perfecting the model before construction begins or solving problems that might occur in the field. Figure 7 illustrates all the tasks associated with BIM software.

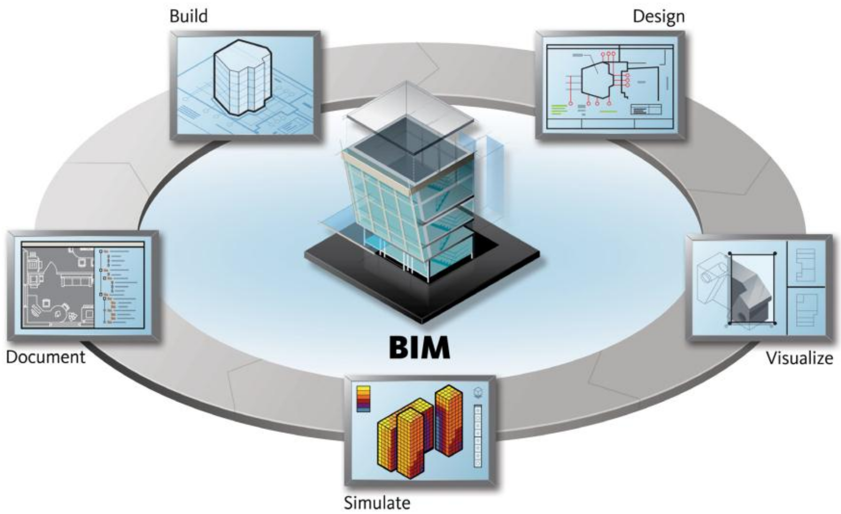


Figure 7: Application and Integration of BIM in Design and Construction (Autodesk, 2012a)

A BIM model contains much more than a 3D structure, different programs allow a project management team to go beyond visual models and assign costs to each item in the building (Smith, 2009). Each part of the model can also be given a phase, and the model can be tracked on a timeline to see what tasks should be completed by a certain date. This data embedded in different elements becomes particularly useful for exporting data to facilitate a cost estimate or create a multidimensional model. Models that display schedule are often called 4D models, and models that display both schedule and cost are often called 5D models. A 4D model simulates the actual building of a project in real time, which allows the owner and contractors to visualize the logistics of construction. A 5D model adds the element of cost to depict the budget progression at certain milestones of construction. Additional tools are available to analyze a building's carbon footprint, predict energy use, and evaluate structural capacity (Autodesk, 2012a). The possibilities for BIM are almost limitless.

Autodesk Revit

Autodesk Revit is considered one of the principal BIM software packages ("Research and Markets," 2011). *Revit* has gained popularity for its user-friendliness, online support and community, and real-world capabilities. The program allows users to create 3D models of whole projects, ranging from the bricks to the columns to the piping (Autodesk, 2012a). Information can also be imported to represent the actual geological location and terrain of a project.

There are three branches of the software: architecture, structure, and systems. Architecture features allow building designers to create 3D models of projects, which can show owners what a building will look like, and it also helps with project coordination. Some of the construction tasks that are associated with the architecture features include building walls, doors, windows, finishes, furniture, landscaping, and site, choosing colors and materials to be used, and various other commands. The systems commands focus on the mechanical, electrical, and plumbing (MEP) components (Autodesk, 2012b). Subcontractors can use the program to coordinate with each other to ensure that there are no clashes where they plan to run conduit, piping, duct, etc. Finally, structure capabilities are more focused on the actual parts that support the building. This includes the structural steel, trusses, slabs, metal decking, and foundation. Structural engineers can use the software to create models of assemblies and simulate, analyze, and design more structurally sound buildings.

Autodesk Navisworks

Autodesk Navisworks is a coordination program that is used by many construction managers that use BIM software. The CM can use *Navisworks* to combine all the *Revit* models from each trade so that the complete project can be analyzed in one environment (Autodesk, 2010b). This is extremely effective for clash detection, which will find areas where multiple models have an element in a given area (”Autodesk Announces Availability,” 2009). These clashes can be fixed before construction is underway; saving time that might have been wasted in the field.

Navisworks can also be an effective tool for simulating a project ("Autodesk Announces Availability," 2009). The user can import schedules from other programs, including *Primavera*, and assign costs for each item in the model; the two features make a 3D model into a 5D model. A model with five dimensions shows a simulation of the project developing over time and increasing in cost. The building model can show exactly what will be completed at any specific date and the cost that will represent progress up to that point. The 5D model is an excellent tool for all members of a project (Autodesk, 2010b). The owner can see the project being built over time and how much money will be spent. The construction manager can plan logistics of the project, including traffic, shipments, and schedule. The subcontractors can understand when their trades will be working. Figure 8 below shows the project viewing mode where the user can control a virtual person and explore the project at any point.

Figure 8: Project Viewing Mode (Autodesk, 2010b)

2.5 Floor Systems

In modern construction a large percentage of buildings are erected using a combination of reinforced concrete and structural steel (McCormac & Csernak, 2012). In steel-frame buildings concrete floor slabs of one type or another are used. The current design of St. Vincent Hospital Cancer Center is a steel frame with concrete on steel decking. The concrete floor systems are strong and have good fire and acoustical ratings; however the construction is expensive, heavy, and may require formwork. The steel frame system offers advantages of constructability, a quick erection, and can increase floor space, as columns are rather small in comparison to concrete columns. In designing a floor system for steel framed building there are many options for the type of concrete flooring and the steel support system of these floors. It is crucial in designing a floor system to use a system that provides fire rating desired, sound and heat transmission, support for dead weight of floor and ceiling situation below, and facility of floor for concealment of MEP.

Each type of floor system offers different advantages and disadvantages that may have a significant effect on the cost and schedule of a project. This means it is of utmost importance to choose a floor system that best satisfies the requirements of the intended building.

2.5.1 Bay Design

Low-rise buildings are buildings that are not very tall in respect to their lateral dimensions (McCormac & Csernak, 2012). There are four groups of steel frames that are used for buildings. The types are bearing-wall construction, skeleton construction, long-span construction, and combination steel and concrete framing. For this project, we will examine skeleton construction frames. The loads in these frames are transmitted to the foundations by a framework of steel beams and columns. All of the dead loads and live loads of these buildings are transferred through the framing system to the foundation.

Concrete floor slabs are almost always used with steel-framed buildings (McCormac & Csernak, 2012). The concrete offers exceptional strength, as well as great fire ratings as concrete is noncombustible and provides an insulated barrier between building floors. On the other hand, the concrete floors are heavy, they require reinforcements, and they can be difficult to make waterproof. The following is a list of common concrete floor systems that are used on steel frames:

1. Concrete slabs supported with open-web steel joists
2. One-way and two-way reinforced concrete slabs supported on steel beams
3. Concrete slab and steel beam composite floors
4. Concrete-pan floors
5. Steel-decking floors
6. Flat slab floors
7. Precast concrete slab floors.

There are many factors that contribute to the selection of the concrete floor system to use, such as loads, fire rating, sound and heat transmission, ceiling types, MEP concealment, time required to construct, etc. A floor system is chosen by the architect that best meets these factors, while at the lowest construction cost. For the St. Vincent Cancer Center an I-beam floor system was chosen with concrete on steel decking. There are many alternatives to this system that may offer advantages, but at the same time affect the cost of the project. The goal of an architect is to design a building that meets the specified requirements, while choosing from a multitude of designs.

2.5.2 Open Web Bar Joists

Open-web steel joists are a very common practice for small steel-frame buildings (McCormac & Csernak, 2012). These joists are small parallel chord trusses that consist of members of bar, small angles, or other rolled steel shapes, as displayed in Figure 9.Steel decking is then usually attached to the joists using welding or self-drilling/self-tapping screws. The concrete is then placed on top of the steel deck. It is a very economical and lightweight type of concrete floor system.

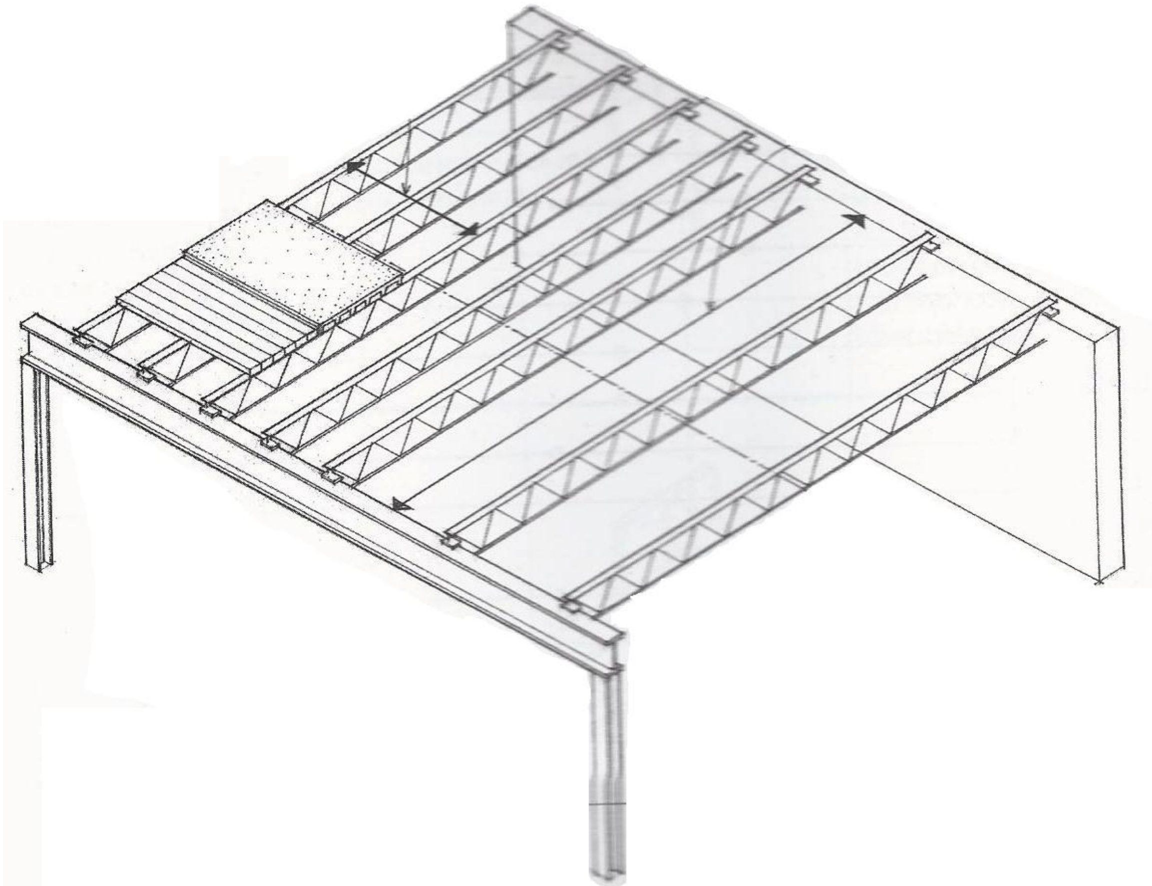


Figure 9: Open-Web Bar Joists (Ching, 2008)

Open-web steel joists are ideal for relatively light loads and structures that do not have much vibration (McCormac & Csernak, 2012). They are well suited for low-level buildings, but they can be used for tall buildings too. The bar joists must be braced laterally to prevent twisting and buckling, using horizontal rods fastened to the top and bottom chords of the joists or diagonal cross bracing.

The open-web joists are very quick to erect and easy to handle. Furthermore, they provide open spaces in the web that can be used to conceal MEP (McCormac & Csernak, 2012). They also offer the ability to accommodate a variety of geometric configurations that a typical steel beam cannot offer, shown in Figure 10. The open-web bar joists offer advantages that an I-beam cannot. Nevertheless there are disadvantages to open-web bar joists. For instance, they need to be pre-manufactured for the job, and may not offer the same strength as an I-beam. It is very important to weigh all options and their advantages/disadvantages when choosing the steel to support a floor system.

Figure 10: Geometric Configurations of Open-Web Bar Joists (Jenson & Moran, 2007)

2.5.3 Cast-in-Place vs. Precast Concrete

Cast-in-place concrete requires a great deal of labor because it takes a significant amount of time to erect the formwork. Furthermore, it requires a significant amount of steel reinforcement from ironworkers. On pour days the area is off limits to all other trades as the concrete must be properly installed and have appropriate time to cure. Cast-in-place concrete requires a great deal of manpower and demands proper scheduling.

Prestressing forces are used to increase the bending, shear, and torsion capacities of precast concrete. The prestressing of the concrete prevents cracking from tensile forces by applying concentric or eccentric forces to the longitudinal direction of the structural element before any other loads are applied to the concrete (Nawy, 2009). This eliminates or greatly reduces the tensile stresses at the critical mid-span so that the sections can behave elastically. In turn, almost all of the concrete can be in its strength, compression.

Precast concrete is an extremely quick way of constructing floor systems, which requires minimal formwork (Nawy, 2009). An illustration of precast concrete planks is shown in Figure 11. Precast concrete is commonly used for roofs, but their popularity in floor use is growing. The prestressing of the concrete reduces deflections and the slab thickness usually by 65 to 80 percent. It also offers savings ranging from 65 to 80 percent of reinforcement. Unfortunately, the saving of materials is balanced by the high cost of materials and cost of prestressing the concrete. Precast concrete also requires more complex formwork, as the sections are usually composed of flanged sections with thin webs. The variation on the surface of the precast makes it necessary to cover with a 1 to 2 inches of mortar (McCormac & Csernak, 2012).

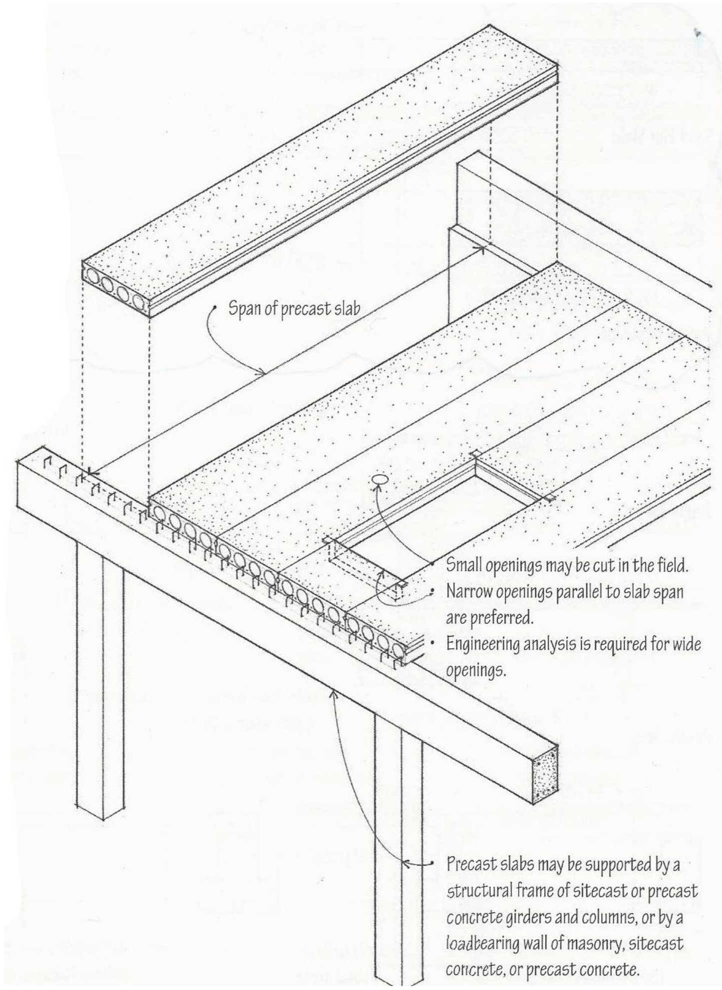


Figure 11: Precast Concrete Planks (Ching, 2008)

A difficulty when using precast concrete is that construction scheduling must be very accurate (Nawy, 2009). In order to coordinate the delivery and installation of the planks, proper lead times must be calculated. The use of precast units can offer some worthy advantages. Generally, the cost of construction difference between prestressed and reinforced concrete is not very large. The long-term savings of precast are substantial; some advantages include less maintenance required, a longer working life possible because of the quality control of the concrete, and a foundation experiencing far less force as the cumulative weight of the building is reduced.

2.5.4 Composite Construction

Composite construction utilizes shear transfer between the steel and the concrete to provide less deflection (Viest, Colaco, Furlong, Griffis, Leon & Willie, 1997). Formed steel deck is used for almost all composite building floors. The strength of the beam is increased, as the concrete serves as a cover plate to the upper flange of the beam. The composite floor system benefits the strength of the system as it makes use of the high compressive strength of concrete. This in-turn causes the steel to be in a greater amount of tension. The strength of both materials is utilized, which results in less steel required to provide adequate design. Composite construction allows the contractor to save money, as less material is needed. The design also can reduce the overall floor thickness required.

Composite construction is helpful when dealing with large loads and long beams (McCormac & Csernak, 2012). As previously mentioned, it can offer great savings and superior strength in design. A disadvantage of composite construction is the cost of the steel anchors and their installation can exceed the amount of savings of other materials. For this reason, it is not recommended to use composite construction for short spans and lightly loaded floor systems. In the St. Vincent Hospital the floor systems are of composite construction. This is important in our analysis and will be used in determining the weight (dead load) of the floor system to be used in the alternative designs.

2.5.5 Site Plan Constraints

When designing the site plan for the duration of the project there were two major constraints that stood out among the rest, limited space and close proximity variables. With the Cancer Center project site being a small piece of the of City Square renovation, there was not much space that Gilbane could use in order to complete the Cancer Center. This constraint took precedence when designing the site plan for the project. However, with the Cancer Center being built in extremely close proximity to the existing parking garage, the use of an expansion joint, specifically, a building separation joint, was necessary.

"Contrary to public perception…buildings move" (Arsenault, 2012).Vertical displacement, thermal displacement and seismic displacement are all possible building movements. Vertical displacement can occur due to different portions of a building having varying heights and sizes, and different types of foundation designs. When different foundations are a factor, the amounts of settlement may be inconsistent. Thermal displacement, also known as lateral shear, may occur because of wind or external building attachments. Last but not least, the severity of seismic displacement, which is considered the worst displacement because the building moves both vertically and horizontally, is based on the scale of an earthquake. Construction forces are rare because construction is not an ongoing factor. Due to all of these displacements, almost all structures contain expansion joint systems. Most externally placed expansion joints are used on a small scale to make connections between smaller structural components, however it is not uncommon to see an expansion joint system that connects entire buildings, similar to the expansion joint system in St. Vincent Cancer Center. These larger expansion joint systems are referred to as building separation joints. When using a building separation joint, the overall intention is to separate a larger building into smaller discreet sections that will be able to act independently when dealing with displacement forces. "It is important to design a building with no critical structures spanning across the joint because the purpose of the joint will be lost" (Arsenault, 2012).

2.5.6 Building Information Modeling (BIM) in Structural Analysis

Using computer software to evaluate a structure is another extension of BIM. One of the key features of BIM is interoperability (Smith, 2009). This is when each firm uses the software most appropriate for its tasks, and the data is exported to another program or shared through coordinating software. Figure 12 below shows the graphical representation of interoperability in construction.

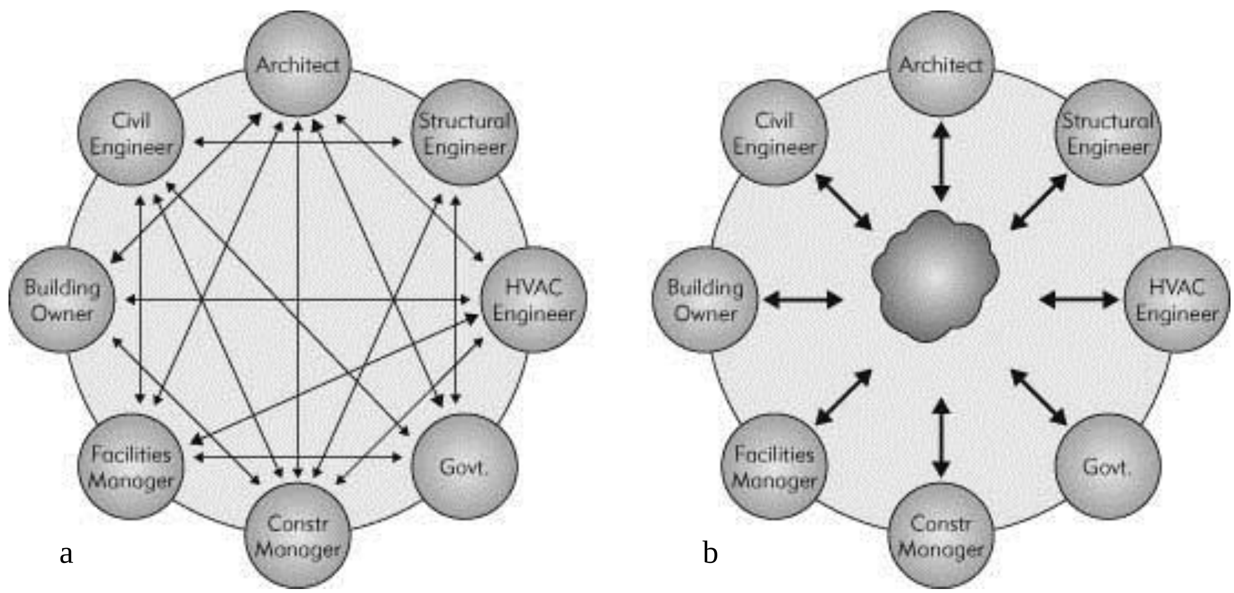


Figure 12: Interoperability (Smith, 2009)

Figure 12a shows that different parties coordinate with other certain parties to complete their task, through meetings, document exchange, and use of specific software. Figure 12b shows that all the data is compiled into one centralized database with interoperable electronic exchange, which can display each party's role in the final product. The final model will usually show discrepancies and items that need to be fixed, and each firm will change their part accordingly. The process repeats itself multiple times throughout a project to ensure the project is completed correctly and on time. Our project will test BIM interoperability through a combination of *Revit* and *Primavera* files integrated in *Navisworks* for the 5D model and structural analysis of *Revit* models with *Autodesk Robot*.

Autodesk Robot is a fairly new product, but is already gaining recognition for its application in structural analysis ("Autodesk Expands BIM," 2008). The software contains its own structure-building interface, or users can import *Revit* files and use the analytical design of the structure to complete various tests and simulations (Autodesk, 2010a). Figure 13 represents all the data that is combined to create the structural documents, including a 3D model, fabrication drawings, and other construction documentation.

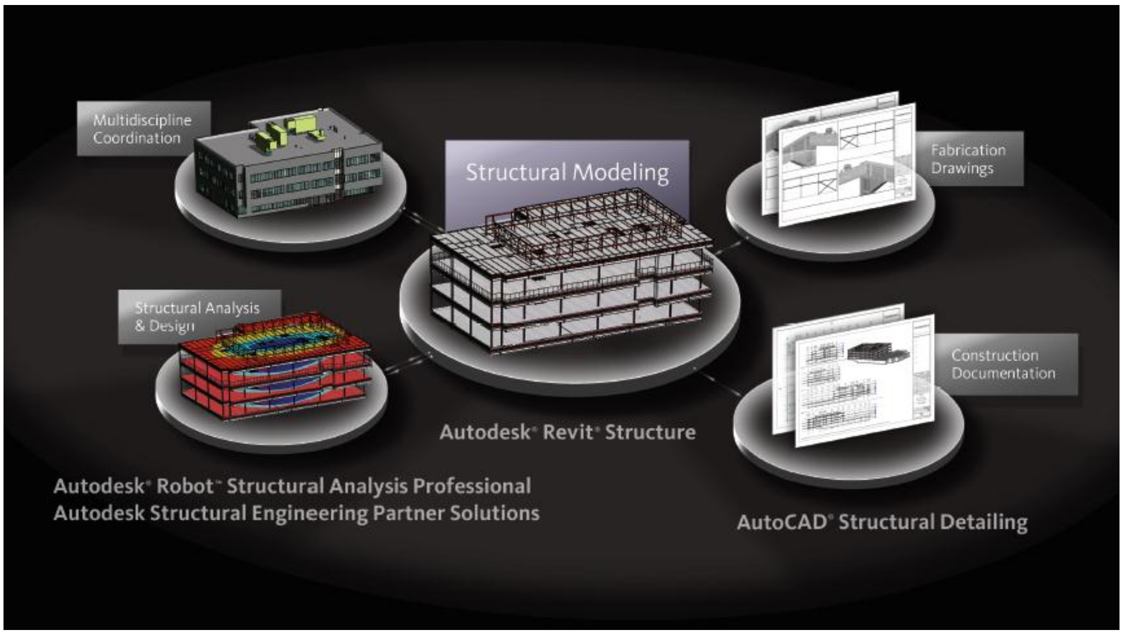


Figure 13: Structural Modeling (Autodesk 2010a)

Robot is another extension of BIM that builds on the goal of interoperability. It allows structural engineers to collaborate with the architect and other trades to improve process efficiency and minimize the potential for errors and omissions. The program allows engineers to analyze concrete and steel members in certain conditions and produces graphical and numerical results of each test. *Robot* considers real-world conditions and regulations; it is integrated with 40 steel codes, 30 concrete codes, and 70 design codes.

2.6 Building Codes

Building codes are a set of rules that establish a minimum level of quality and safety for all construction ("Public safety," 2012). They are intended to protect public health, safety and general welfare. Engineers and architects must follow the appropriate building code for the appropriate occupancy classification in the design of a building. *The Board of Building Regulations and Standard (BBRS)* administer the Massachusetts's building code. The 8th edition is the current publication of the building code, which uses a combination of codes from the *International Code Council (ICC)* and separate amendments for Massachusetts. The code is altered often as new codes are adopted. On March 1, 2012 the *BBRS* will adopt the *IECC 2012*, which will take full effect after a full year.

The current building code is a compromised version of the *International Building Code 2009* (*IBC*), which originates from the *ICC*. The *IBC* should be used in compliance with the Massachusetts Amendments to the *IBC*. The purpose of the *IBC* is to ensure safety of buildings by setting limits on design values for the structure design (*IBC*, 2009). In any case where the codes and regulations do not agree with each other, the most restrictive code should be used.

St. Vincent Hospital will have occupants that are receiving medical treatment, surgical processes, nursing, and are generally incapable of self-preservation so the building and design should comply to all codes and regulation of the *IBC* occupancy of 08.3 Group I-2 (*IBC*, 2009).

3.0 Baseline Evaluation of St. Vincent Cancer Center

To better understand the structural components of the existing design, a baseline 3D *Revit* model of the foundation and the structural frame was created from the project's two-dimensional contract documents. The 3D *Revit* model was exported and imported into *Robot software* for further structural analysis. Also, a simple, trial structural frame was transferred from *Revit* to *Robot* to make sure an understanding of the computational and functional capabilities of this software application was reached. Finally, to better understand the construction process used by the builder of this project, a cost analysis and baseline schedule was created using bid documents, construction photos, and the contractor's schedule. This was followed by documenting the contractor's site plan during construction to determine the amount of space allotted for drop off of supplies.

3.1 *Revit* Model

Before building and analyzing models of the proposed designs, the team investigated the current structure to use as a benchmark for comparison. A 3D digital model was created using *Revit* software and 2D structural drawings as provided by Gilbane[1]. Gilbane also provided its *Navisworks* 3D model for the project, which was helpful in showing aspects of the structure that were not clear in the 2D drawings. The reference drawings the group used were the actual structural drawings that were up to date with changes and approved by SMMA, with an example shown in Figure 14. The column line and bays are highlighted in blue in the figure.

[1]Drawings: S0.01, S1.01, S1.02, S1.03, S1.04, S1.05, S1.06, S2.01, S3.01, S3.02, S3.03, S4.01, S4.02

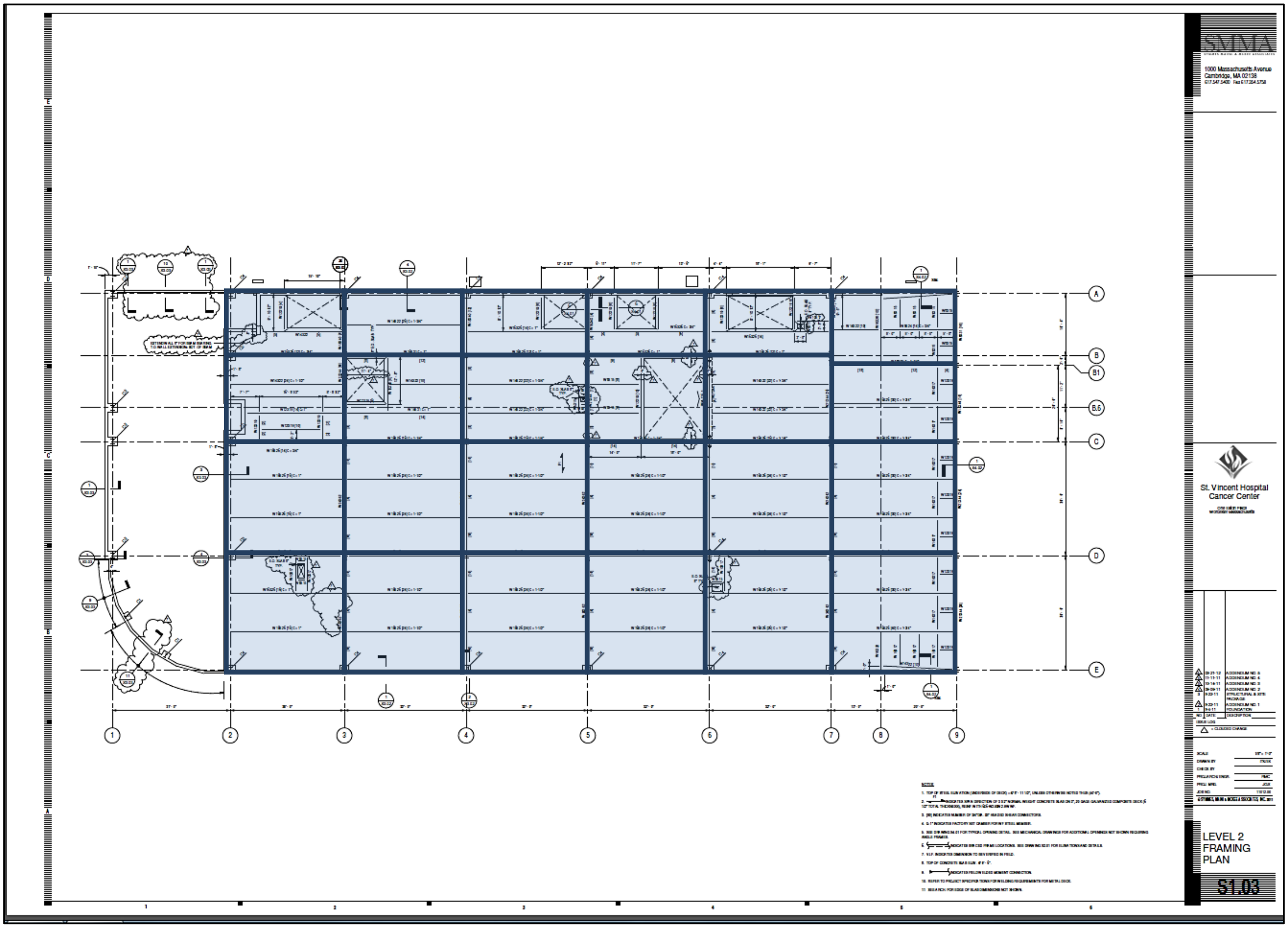


Figure 14: Example of SMMA Structural Design Drawing (S1.03 Level 2 Framing Plan)

The structural components of the floors at St. Vincent Cancer Center consist of a concrete foundation and an open mezzanine area on the first floor. The I-beam floor systems on the second and third floors are rather similar with bays of 32’x30’. The beams for the second floor are W16x26 and on the third are W16x24. The interior girders of both floors are W24x62. The beam systems for both floors support a composite, concrete slab on steel decking. An isometric view of the building’s levels is shown in Figure 15. The live and dead loads were added (see section 3.2) on each of the floors in *Revit* to create a basis for the calculations in *Robot*.

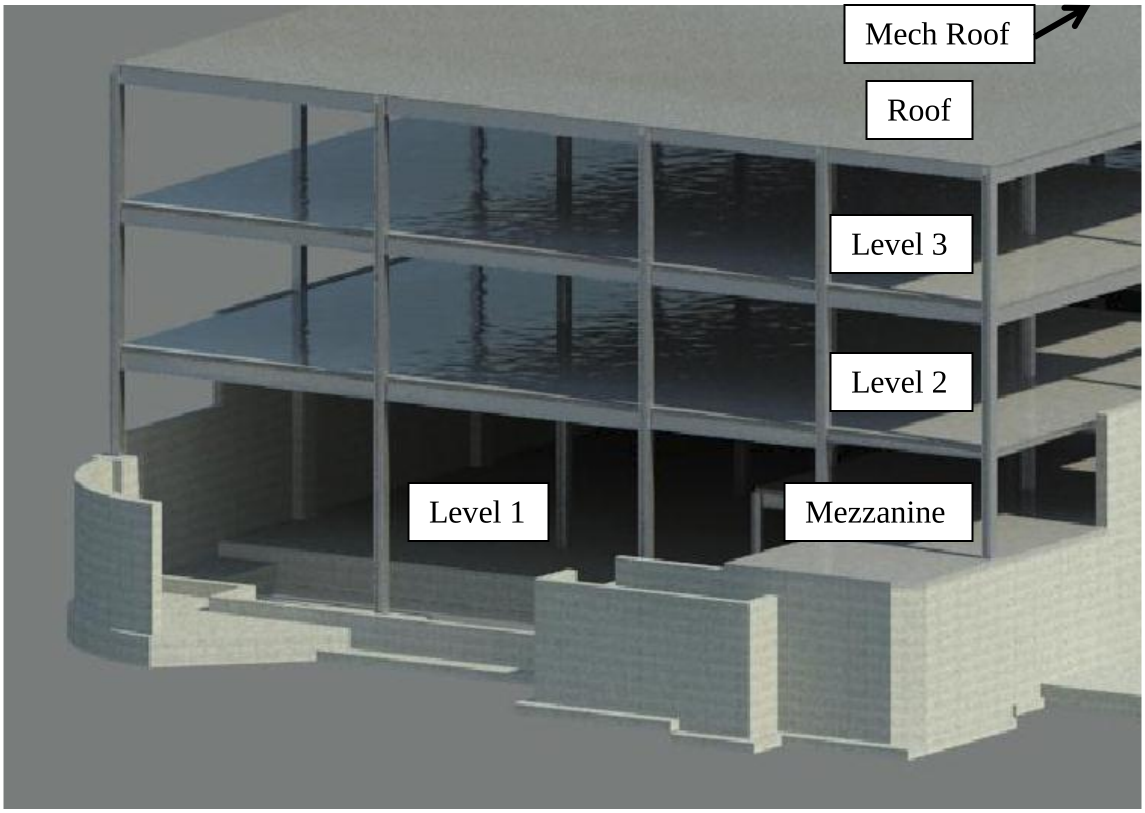


Figure 15: Isometric View of Building's Levels

The *Revit* model was first setup with gridlines and all the “top of steel” elevations to represent levels one, two, and three, the mezzanine, and the roof. The construction of the model started from drawing S1.01 to virtually construct the foundation walls and footings, and used the footing schedule (see Appendix C) for the isolated footing sizes. The foundation drawing also shows the specialized concrete vaults that will house medical equipment that emits radiation. Detail drawings were reviewed to confirm foundation wall thicknesses, slab thicknesses, and footing depths. Figure 16 shows an example of a detail drawing for a wall section and footing along gridline A.

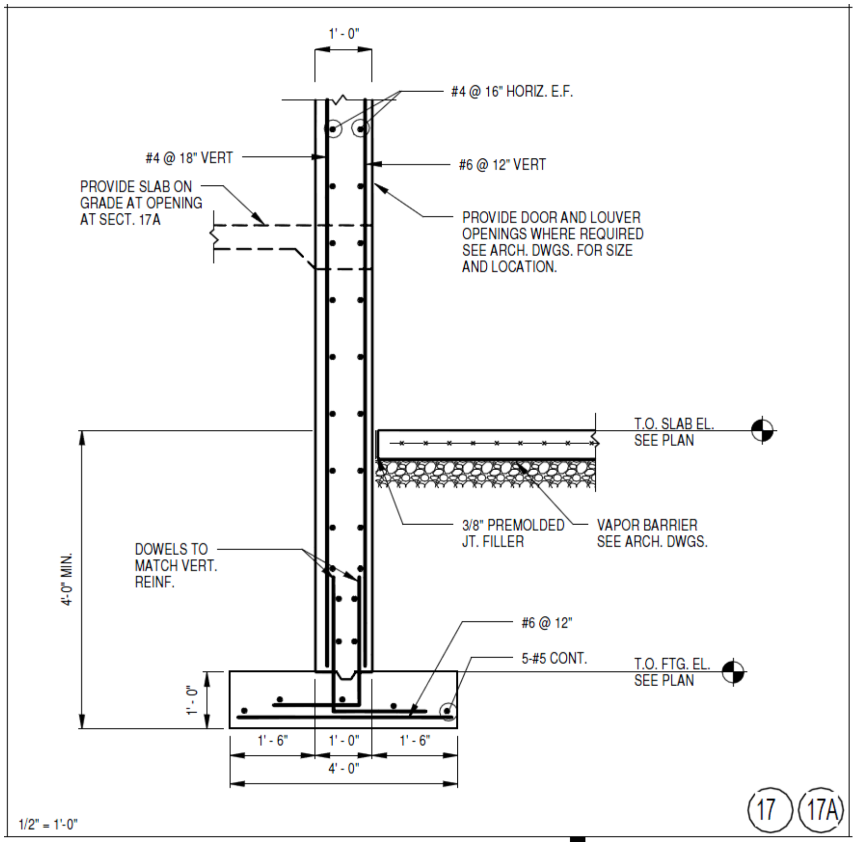


Figure 16: Example of Structural Detail Drawing (S3.02)

The radiation vault required extra attention to detail because it has concrete walls with various widths and shapes, ranging from 2’-6” to 7’-9” in thickness. The vault also has varying elevated slab thicknesses, with some areas having 48”, 66”, or 87” thick concrete slabs. Rough hand drawn sketches were made to help identify and organize all the vault dimensions into single, easy-to-read plans, which helped streamline the *Revit* design and modeling process for the unique concrete structure (see Appendix D). Renderings of the 3D model foundation created with *Revit* can be seen in Figure 17.

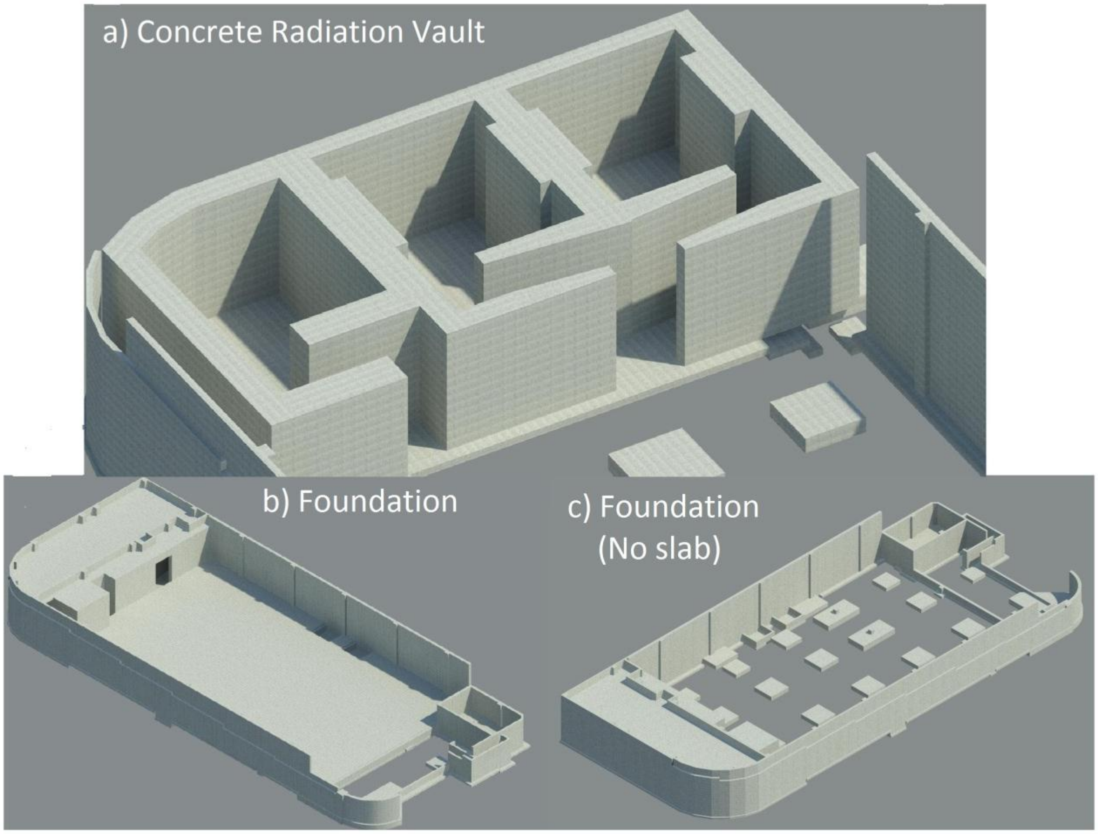


Figure 17: Foundation Renderings from *Revit*

As is the case on the construction site, construction of the structural steel fame model within *Revit* could begin once the foundation was completed. Virtual steel construction began with column erection, per details depicted in the column schedule (see Appendix C). Girders were placed along the column lines following the design shown in the structural drawings, and subsequently beams were inserted in the required layouts until all the levels were completed. The *Revit* model contains both the design model and an analytical model, which is useful for structural analysis. After finishing the framing of 3D elements, the entire analytical model was reviewed to ensure each steel connection was in accordance with the drawings. The drawings stated that any non-detailed connections were to be considered pinned connections, and those marked with triangles were moment connections. Figure 18 shows a moment and pinned connection adjacent to each other in the St. Vincent building; this figure also illustrates the difference between each notation on the drawings: moment connections are shown with small triangles and any other unmarked connections are pinned. Figure 19 is a plan view of the lateral frame and columns on level 3 that makeup the moment frame (highlighted in red).

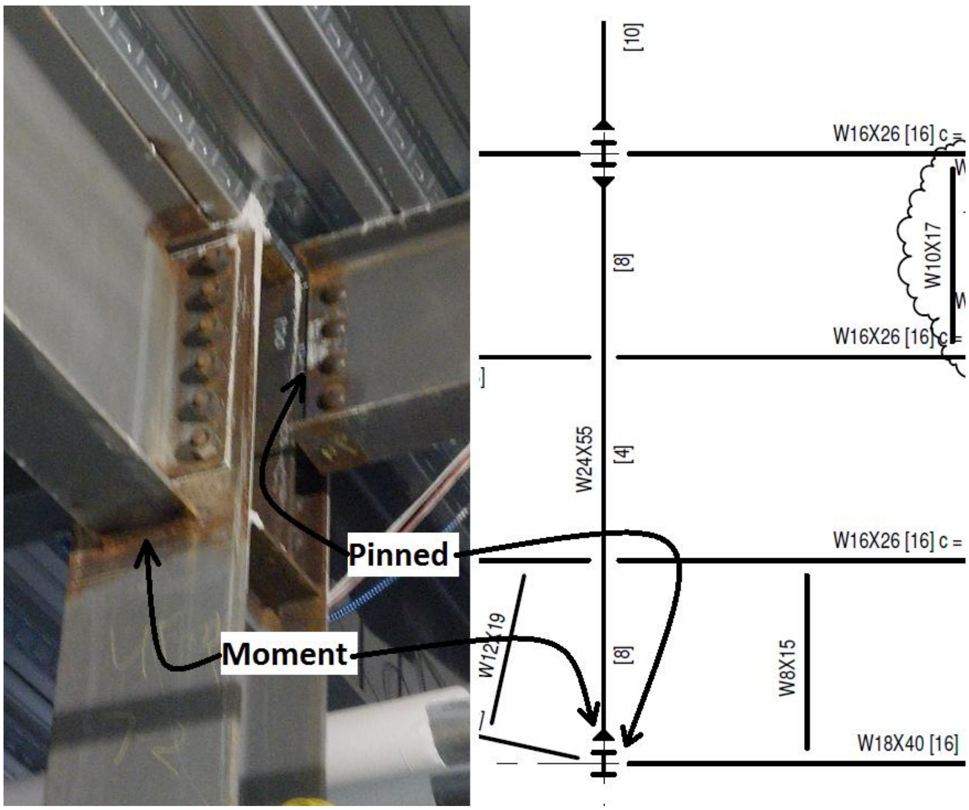


Figure 18: Steel Connections- In Building vs. On Drawing (S1.04)

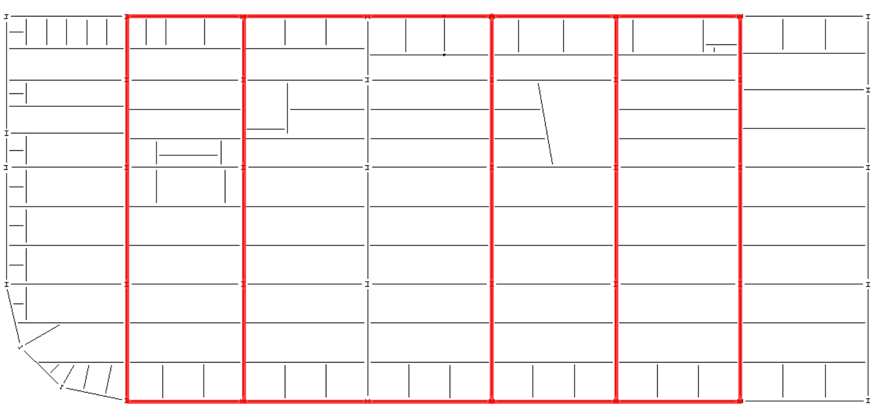


Figure 19: Lateral Moment Frame on Level 3

A properly designed analytical model aided in smooth exports of information (geometry and attributes) from *Revit* to *Robot* for structural analysis and design. A *Revit* rendering of the structure with steel framings is shown in Figure 20.

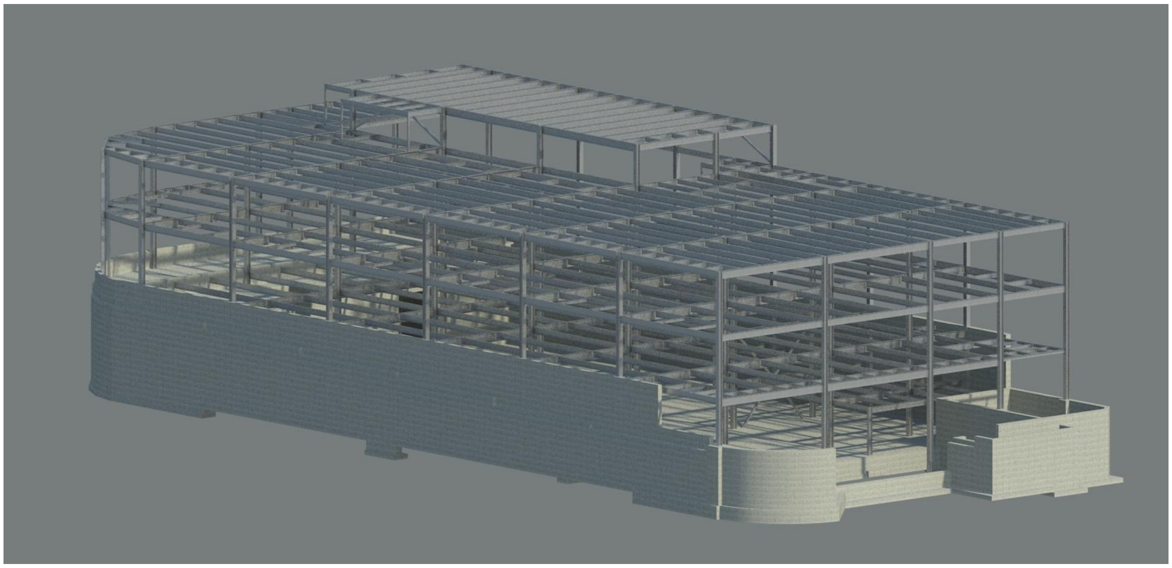


Figure 20: Baseline Model Rendering (No Elevated Slabs)

The last elements placed in the 3D structure were the floor slabs. The slab on grade sits above compacted ground and the isolated footings and is in a different *Revit* family of elements than the elevated slabs. Families are different groups of elements in *Revit* that are categorized by their building function, for example floors, column, walls, doors, windows, etc. It was important to keep elements grouped in particular families in order to keep track of the many items in the model. This data contained in the model was later exported to a spreadsheet to determine the quantities associated with the materials in the structure. Slab on grade is in its own family because it is differs from elevated slabs in purpose, structure, and the way it acts when loaded. The elevated slabs have concrete and metal decking, and the roof slab is mostly just metal decking with insulation on top. The final baseline *Revit* model can be seen rendered in Figure 21.

Figure 21: Final Baseline Model Rendering

Once the model design was complete, the design load tools were used in *Revit* to add loads to the structure in order to prepare the model for export to the *Robot* software.

3.2 Design Loads

The design loads are critical to the structural analysis of a building. The design criteria for the analysis were provided by the structural engineer and are outlined for the building in the structural general notes and schedules. The applicable code identified is the *Massachusetts State building code – 8th edition*. The performance requirements are defined in the structural project specification to use allowable stress design (ASD). The service-load levels to be used are identified in the structural plans. For a conservative analysis of the floor and roof systems, wind loads were not included in the analysis, as these generally provide uplift to the roof system, which counteracts the gravity loads. Also, the seismic loads were not used in the analysis as their major effect is on the frame of a building. The design live loads that were used for analysis can be seen below in Table 1.

Table 1: Design live loads

Area	Service Load
Ground Floor on Slab on Grade	250 psf
Vault Slabs subject to automobile traffic	250 psf
Office Areas	100 psf
Mezzanine and Stairs	100 psf
Mechanical Penthouse	150 psf
Snow Loads (without drift load)	38.5 psf

The next step was to determine the dead load for the floor system of the building. The Vulcraft catalog was used to determine the dead load of the 3 ½ inch normal weight concrete slab on 20 gage steel decking. The value provided by the catalog was 63 psf ("Vulcraft steel deck," 2008). The current floor system on floors two, three, and parts of the roof consist of this normal weight concrete on steel decking. On the roof there are areas that have 1 ½ inch 20 gage or 18 gage steel deck without concrete. The weight of the steel used for dead load on these areas was 2.14 psf and 2.82 psf, respectively, which was based on the weight of the steel decking. The insulation on top of the steel deck is neglected, as the weight of the insulation was not significant.

Snow loads were provided by the design criteria; however it was found that snowdrift calculations were not included. The determination of the snowdrift load was calculated at maximum intensity using information provided by the *Massachusetts State Building Code* on snow loads ("Structural Loads," 2001). The maximum drift was applied to the entire roof system, to ensure that the design meets the worst of snow conditions (see Appendix E). The maximum load was found to be for leeward drift and to be 89.25 psf, which is a very substantial live load for the design of the roof system. This load would be applied to the snow load and the entire roof area that requires snowdrift calculations to be included as specified in *ASCE 7*, a standard code for the design of snow loads.

Once all the service loads for the floor and roof systems were established, the ASD combinations provided in *IBC* (*International Building Code*) section 1605.3.1 were used. The service loads were not factored in *Revit* because *Robot* is capable to factor the loads in its analysis. We chose not to factor the loads in *Revit* so that if it is needed, verification that the correct load was imported to *Robot* can be made. The loads were then factored using the factoring feature provided by *Robot* (see Appendix G). The dead and live loads applied to *Revit* can be seen in the Figure 22 below, with the yellow loads defining live loads; they are larger in magnitude than the dead loads of the floor. Although the picture shows the loads acting on the perimeter load, they are applied evenly throughout the floor system.

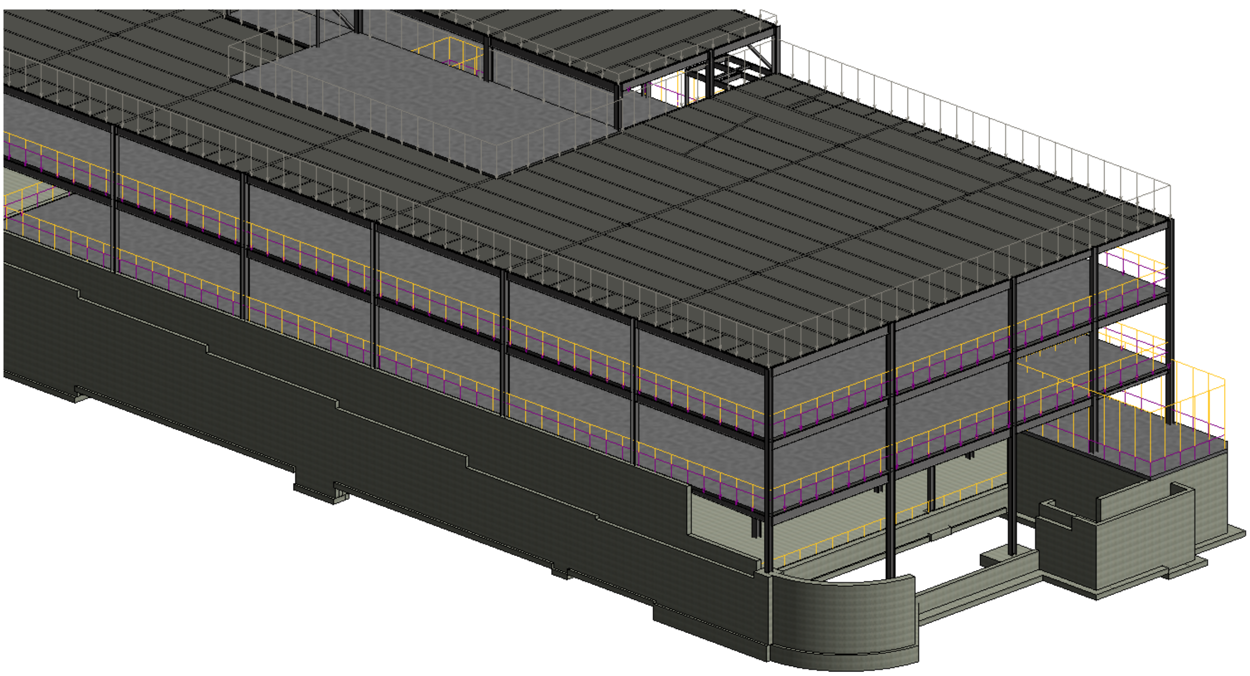


Figure 22: Baseline Model with Loads in *Revit*

3.3 Learning *Robot* and Trial Runs

Before the baseline *Revit* model for the building was exported to *Robot* for analysis, the interoperability between the two programs was explored by creating a simple structure in *Revit* and then exporting it to *Robot* (See Appendix H). To ensure visual results, the simple structure had several types of loads and framing. The model consisted of an I-beam bay perimeter with open web bar joists spanning the bay and an elevated concrete slab on metal decking. The model also had various point and area loads among it, both dead and live load combinations. When trying to import the first simple model into *Robot* a helpful feature gave notification that the joists in the model did not meet design requirements for that joist size- the bay in the model had a smaller span than the minimum joist span. This notice illustrated one of the safeguards that are embedded in *Robot* to assist users with designing structures within design codes and requirements.

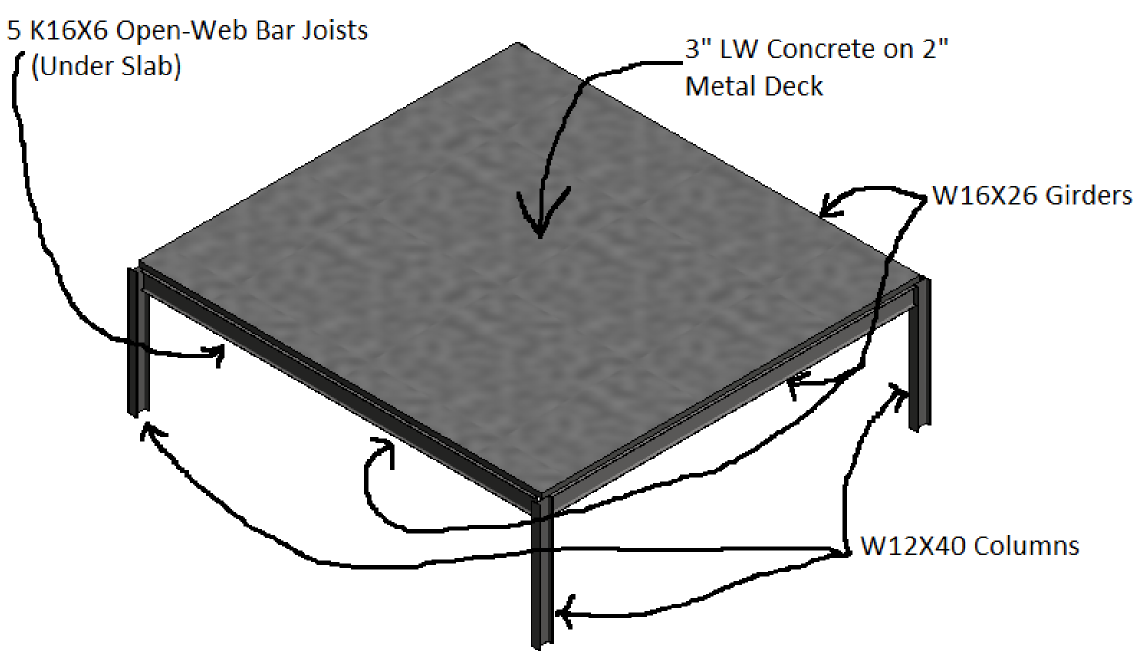


Figure 23: Simple Structure Design Specifications (*Revit* model)

After amending the design to meet span requirements in *Revit*, a simple model was ready to be exported to *Robot*, shown in Figure 23 above. A dead load was added to represent the weight of the elevated slab on the steel and several live loads, both area and point loads were defined. The results from analysis of these forces can be seen Figure 24 below.

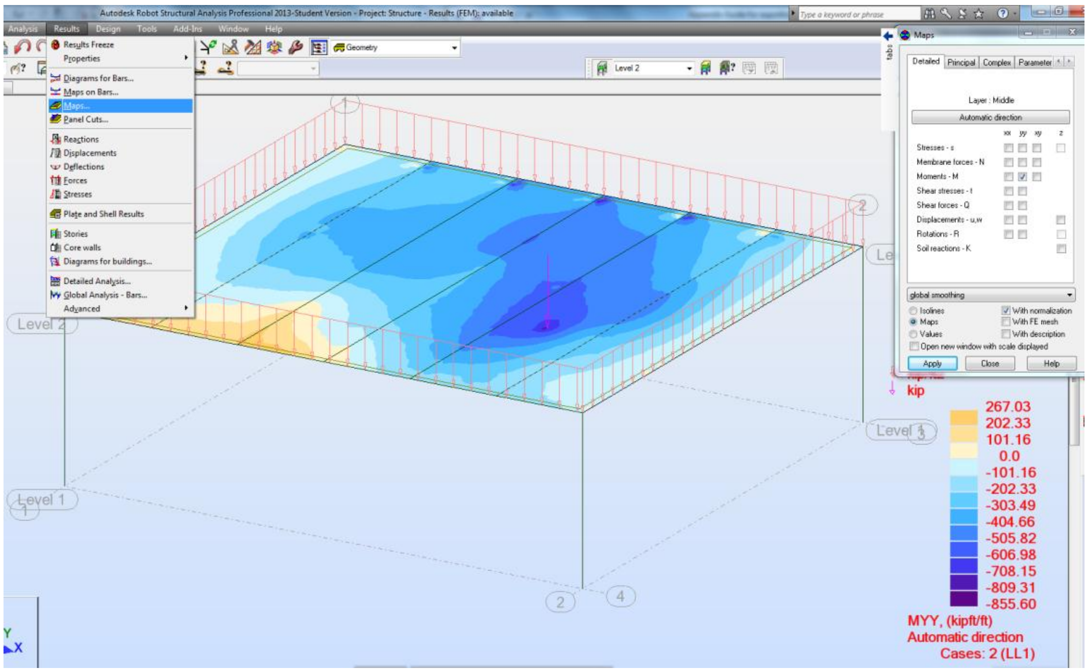


Figure 24: Simple Structure Analysis in *Robot*

The *Robot* results show that the moment generated by the action of live loads slab is higher in the darker blue and purple regions of the diagram. The maximum moment of the simple structure with the large live-loads was 4,329 kip-ft, which is extremely high. If this simple structure were actually being tested for structural integrity, the structural steel designer would have to redesign the layout with stronger, more-reinforced framing.

The trial design was a very important learning step to develop an understanding of how to use *Robot* on a basic level before trying to import complex models of floor systems. Further, resources from the Autodesk website were used as a guideline to the integration of *Revit* Structure and *Robot* Structural Analysis Professional (Autodesk, 2010c). These checks inspected each structural element and verified that they are correctly supported. When there are problems with the model, error messages are displayed. One of the checks inspects the relationship between an element's physical location and its analytical line. It is here that adjustments were made to the tolerances to 12 inches for all tolerances. This can help to tremendously reduce errors. The notes summarizing the trials and errors are displayed Appendix I.

It was determined that the maximum moment diagram in the yy axis is the best way to display results. The orientation of the x-y-z axes for the model can be seen below in Figure 25, as the yy axis is the bending axis of a 3 dimensional building model. Graphing the MYY (moment in YY axis) was done throughout the alternative designs and facilitated the evaluation of the system's structural performance of the designs.

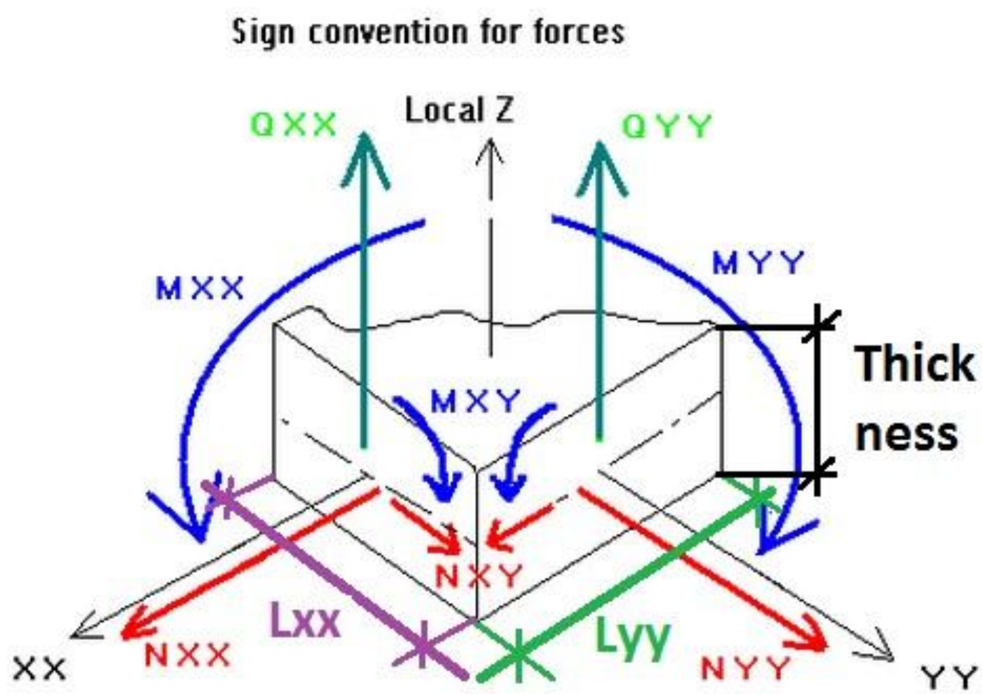


Figure 25: Sign Conventions of *Robot*

It is important that the sign conventions are understood in the analysis of the model. In Figure 25 above it can be seen that the MYY is the bending moment for a floor system. This axis is standard nomenclature for *Robot* analysis and is transverse to the building. The z-axis is the direction of the design loads for the floor system and acts downward on the floor system. For analysis of the loads the force in the z-axis (F_Z) shall be used. Further sign conventions of *Robot* software can be seen above in Figure 25. The orientation of the building according to these sign conventions can be seen in Figure 26.

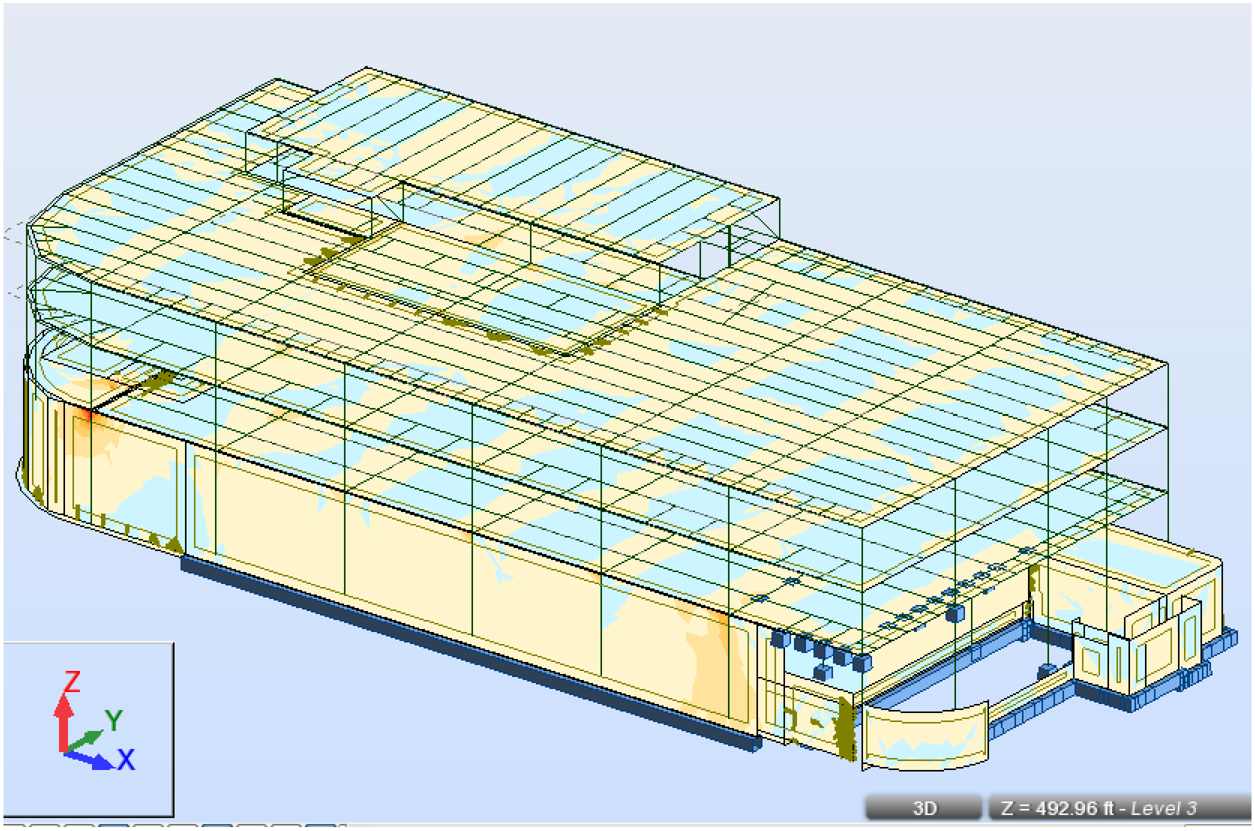


Figure 26: Axis Orientation of 3-D *Robot* Model

The moment in the yy direction provide the bending moments on the beams. The values range from positive values to negative, as the moment from adjacent bays is transferred. The maximum moment for the bay is the difference in the value of the highest and lowest moment. Finding the maximum moment of a given bay provided a strategy to check the strength of the beams to make sure that the alternative systems were designed to meet structural requirements.

3.4 *Robot* Analysis

As the initial exports of the baseline model began, several errors were observed. *Robot* would not allow calculations in the software, citing FE (Finite Element) mesh issues. The FE mesh is a feature of *Robot* that effectively takes the analytical model from *Revit* and creates a mesh surface along with objects and connections. It was determined that the error was hidden somewhere in the foundation walls. After further examination, it was confirmed that the problem concerned the curved corner of the foundation wall, and the FE mesh could not form around this surface. In order to complete the analysis, the complex corner components were replaced with basic wall elements in *Revit*. With the simpler foundation, the *Robot* calculations and analysis could be done with only several minor warnings.

The four baseline warnings received in *Robot* can be seen in Figure 27 below.

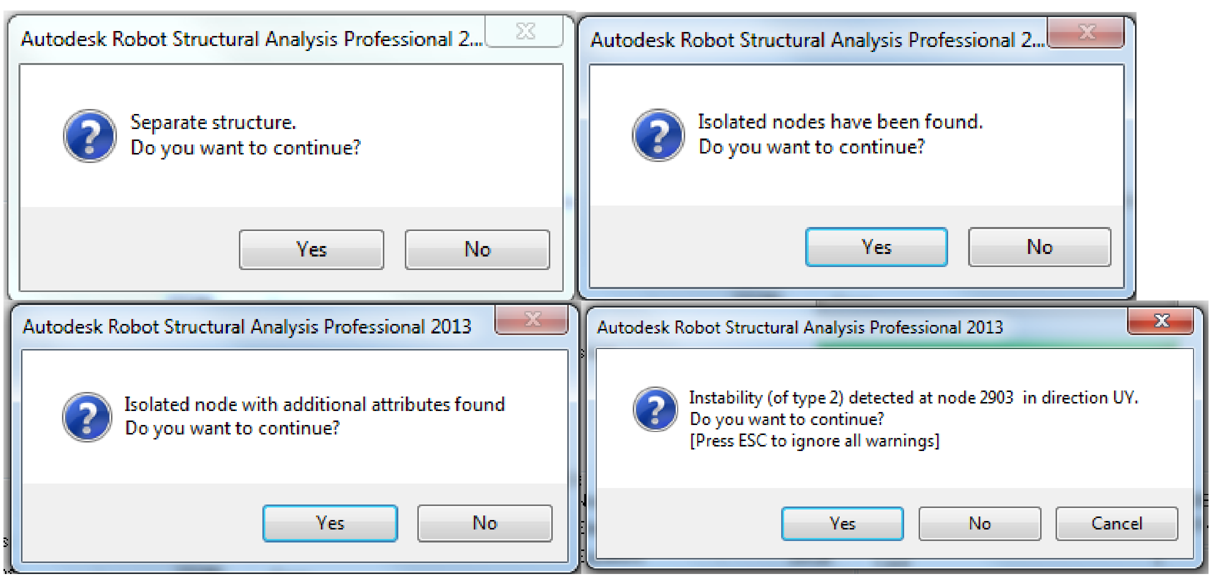


Figure 27: Baseline Model *Robot* Analysis Warnings

The first warning stated that the model has a separate structure within it. This indicated a part of the foundation wall was separate from the rest of the structure in the analytical model. It was assumed that the architectural curved wall, stairwells, or other irrelevant, nonstructural element was triggering this warning and continued. Both isolated node warning were difficult to address because details on which nodes had errors were not available. This warning meant there were nodes that were not connected to the structure and were isolated. This warning could also mean that these nodes have zero displacement, usually occurring at the supports. Because the nodes at issue could not be determined, the calculations were continued. The final warning gave a specific node that had instability in a certain direction. It was found that *Robot* was inconsistent, identifying different nodes with instabilities in different directions when trying to export multiple times. Correcting this inconsistent warning was problematic, so the team continued onto the results.

The *Robot* analysis provided the team with results reflecting the effects of the design loads. Because the model was defined in accordance with the structural drawings, the calculations produced favorable results that all members complied with the structural requirements and specific codes. The architect and structural engineer have already completed a structural analysis of the building, so the consistent results were not surprising. Figure 24 in section 3.3 shows the baseline *Robot* model with a color scale map of area that have the largest moment in the positive and negative YY axis.

The Robot structural analysis of the baseline design was studied to ensure that the Robot software has interpreted the Revit model correctly. The maximum moment of a floor system on a beam was compared with the maximum moments of I-beams found in the AISC Steel Manual. The results proved that the beam systems in place with the inputted Robot loads are sufficient.

For example, on floor three the mechanical penthouse shows a higher moment in the mechanical penthouse area (due to the increased live load required). All other floors have an evenly distributed load throughout the floor and therefore are uniform. It is interesting to observe that all floors are designed with the same beam system. This implies that the floor system may be overdesigned but was most likely done so for constructability purposes to simplify fabrications and construction handling in the assembling of the structure. However, after completing hand calculations for the beams it was determined that *Robot* was having errors with the load paths throughout the model.

An analysis of the *Robot* software ability to interpret and distribute the loads correctly throughout the building was necessary. When the moments of a beam were determined by hand calculations in Appendix F: Baseline Model Structural Hand Calculations, the results from *Robot* proved to be inaccurate. The team verified that the design loads were imported from *Revit* correctly and that the factoring was completed using the worst-case scenario of the eight ASD load combinations (see Appendix G). Two beams were analyzed with hand calculations, but the *Robot* software had a major difference in the forces and moments that acted on these beams. It can be seen that in Appendix F, that the maximum bending moment for a W16x26 beam on floor 2 was calculated to be 208.64 kip-ft. The *Robot* moments were much smaller than this, as seen below in Figure 28. A girder was checked and found through hand calculations that is should have a moment of 451.94 kips-ft, as seen in Figure 29. The moment is also much smaller in the *Robot* model. This meant that there was an error in the *Robot* program, and could have been from a number of factors. Most likely, the loads are being dispersed throughout the model incorrectly as *Robot* has interpreted nodes and the load paths incorrectly.

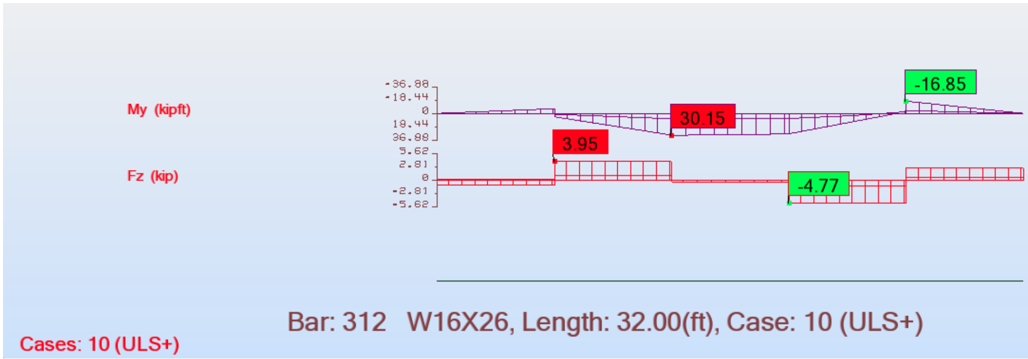


Figure 28: Moment in W16x26 I-beam Joist

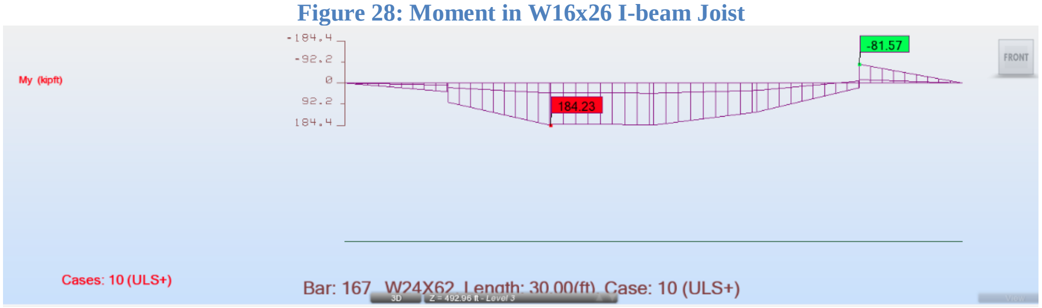


Figure 29: Moment in W24x62 Girder

To check that the correct load was being applied hand calculations were completed on page 3 of Appendix F. It was found that the force in the Column D6 from the roof load should be an axial force of 124.70 kips. However, the *Robot* model showed a much smaller load in for the F_z axis as seen in Figure 30. This check demonstrated that the loads were not being distributed properly and that the *Robot* model has complications.

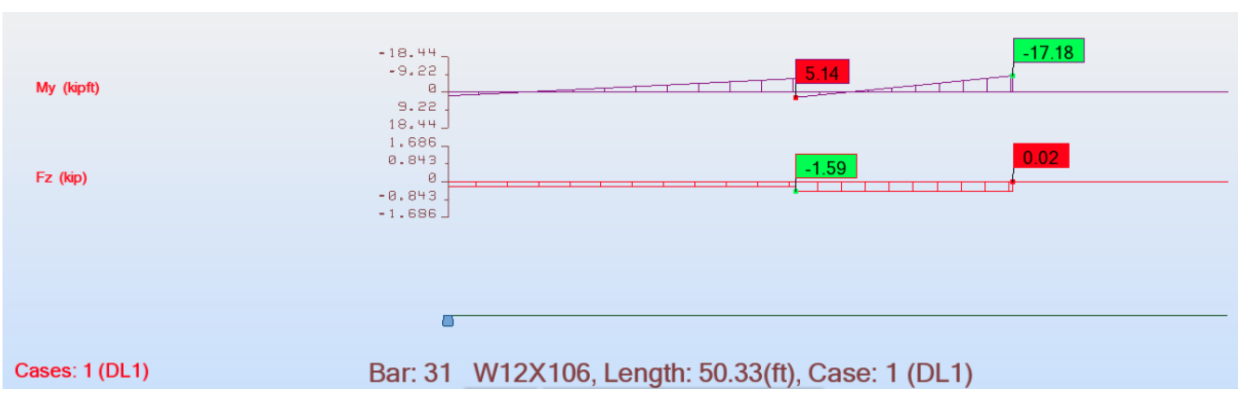


Figure 30: Forces in Column D6

It can be seen that in Table 2 that the *Robot* calculations are very different than the hand calculations. The numbers seem to be consistently lower for the *Robot* analysis. The interpretation of an incorrect load path in *Robot* can be concluded from these results.

Table 2: Comparison of Hand and *Robot* Calculations

Structural Element	Floor	Hand Calculation	*Robot* Calculation
W16 x 26	2	208.62 kip-ft	27 kip-ft
W24 x 62	3	451.94 kip-ft	265.8 kip-ft
Column D6	Roof	Fz = 124.7 kips	Fz = 1.61 kips

For the scope of this project, *Robot* was still used for evaluation of the alternatives, despite that the model used provides faulty results. The moment diagrams show moment distribution throughout the floor systems, even though it may not be the correct magnitude it will be used to evaluate moment distribution for each alternative floor system. The results provided by *Robot* will be used to make an analysis of the floor systems design and the differences between the alternate designs will be used to evaluate the design. The *Robot* model shall not be used to verify that the design meets structural capacities of the building, although all of designs will be designed to meet the requirements of the design loads.

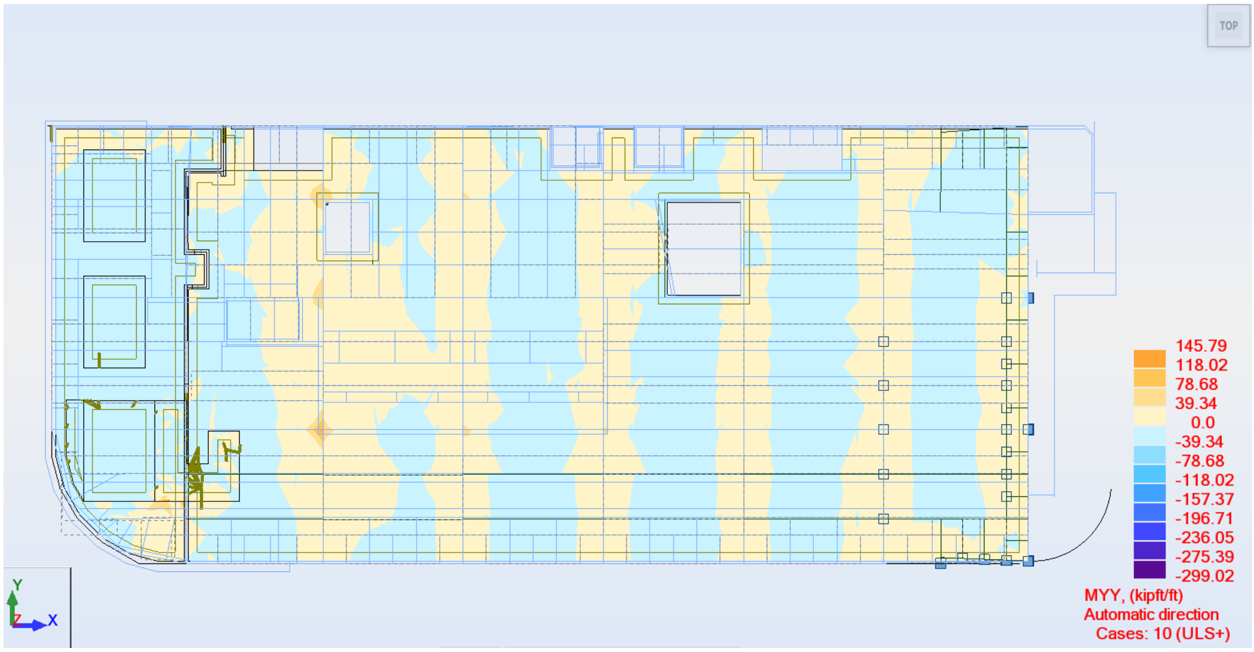


Figure 31: Baseline Model MYY Floor 2

Figure 31 shows the moment distribution throughout the floor system. This floor has a live load of 100 psf and a dead load of 63 psf for the concrete slab on deck. The load is distributed from one bay to another. The moment connections are along the girder lines that run in the y-direction (up and down in the figure). It can be seen that at the moment connections there is little or no moment. In the center of the bays of the y-axes column line the moment is the greatest negative value. The maximum moment of the beams running in the y-direction would be the highest positive value and the lowest negative moment value. This makes sense in regards to a moment diagram as seen below in Figure 32. The figure shows that the moment is greatest at the mid-section of a beam. The force in the Z direction will make the moment begin positively, but then the design loads will increase in moment in a parabolic fashion in the negative YY direction.

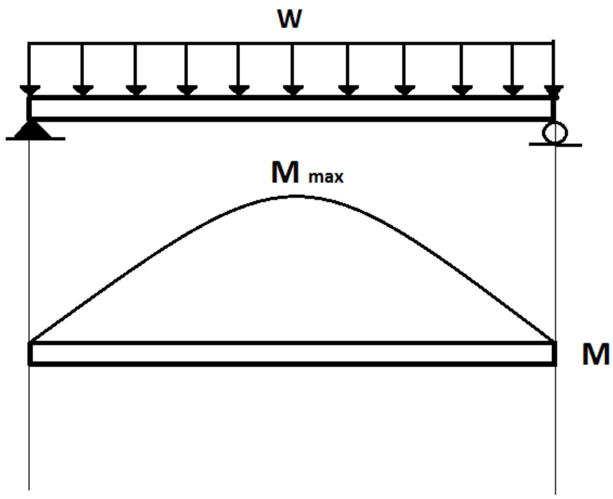


Figure 32: Moment Diagram

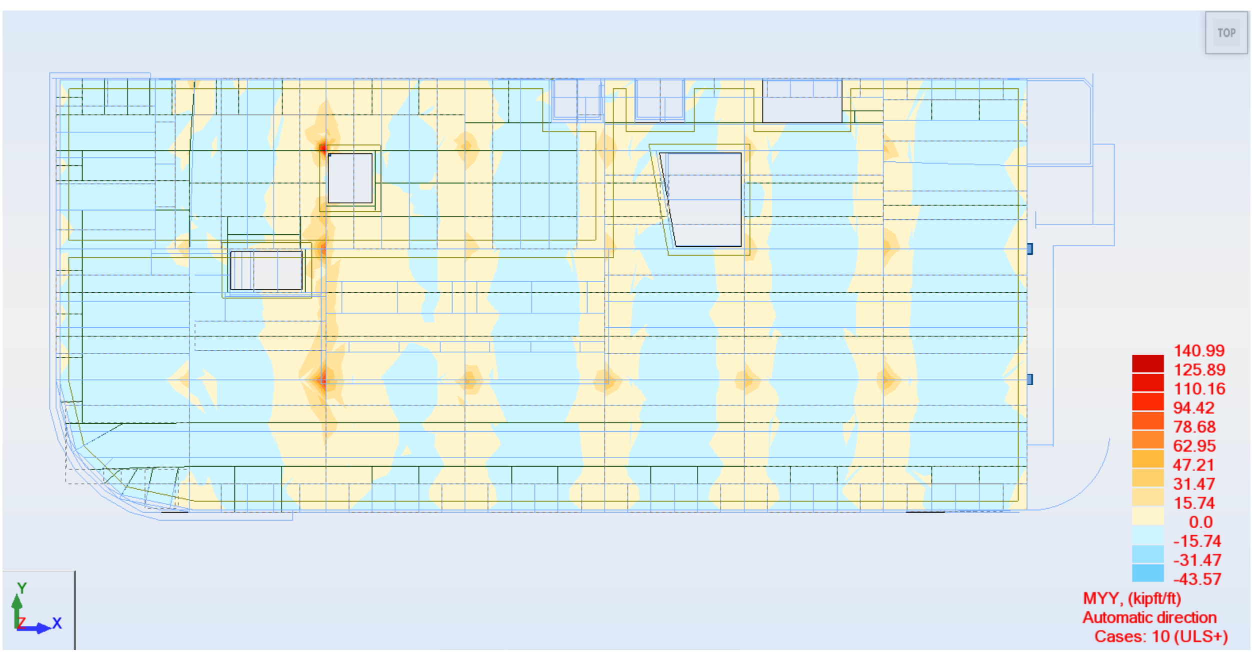


Figure 33: Baseline Model MYY Floor 3

The baseline model MYY Map in Figure 33, displays the moment distribution throughout the third floor of the building. This area is intended for an office area and has the same design load that was specified above for Figure 31. The moment distribution for this floor is similar to that of floor 2. The moment is similar along the column line in the y-axis; however it is very different along the x-axes. Once, again columns seem to have the greatest moment.

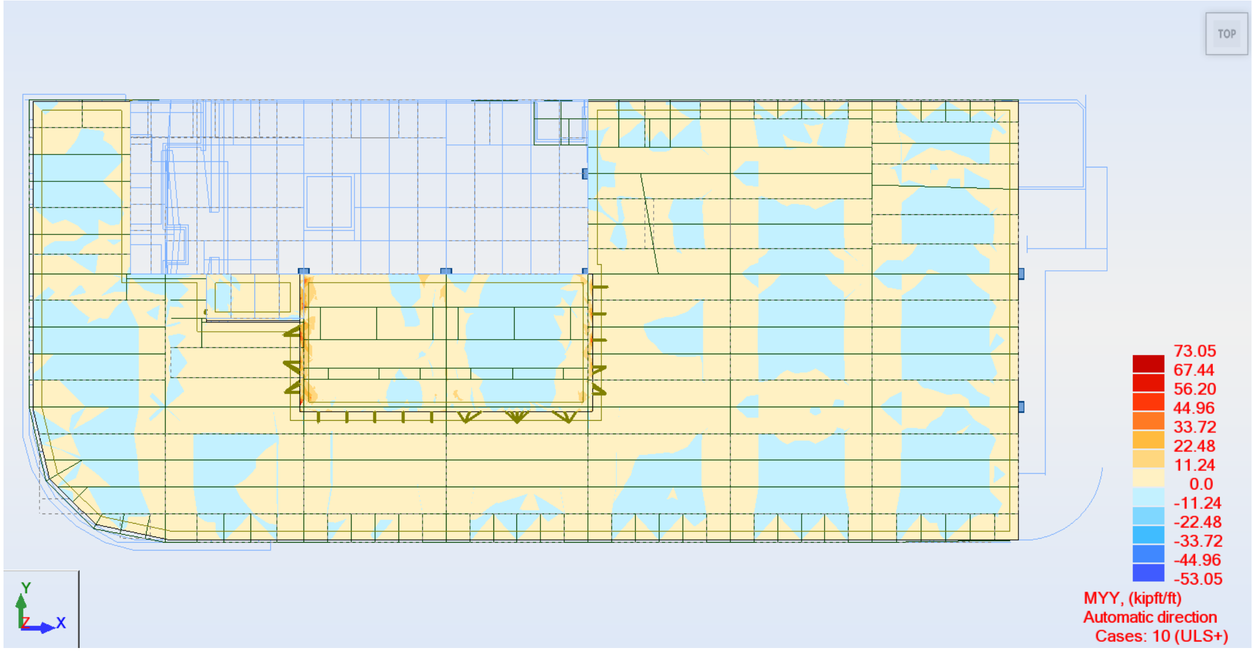


Figure 34: Baseline Model MYY Roof

In Figure 34 the moment distribution of the baseline roof design is shown. The design loads used for the roof are much higher than the floor systems. The design loads comply with section 3.2, and account for the snowdrift on the roof. This roof system has more I-beams than the floor systems. It can be seen that the moment distribution provides the greatest negative value in the center of bays. The columns at the corner of the bays do not have a high concentration, as seen on the other floors.

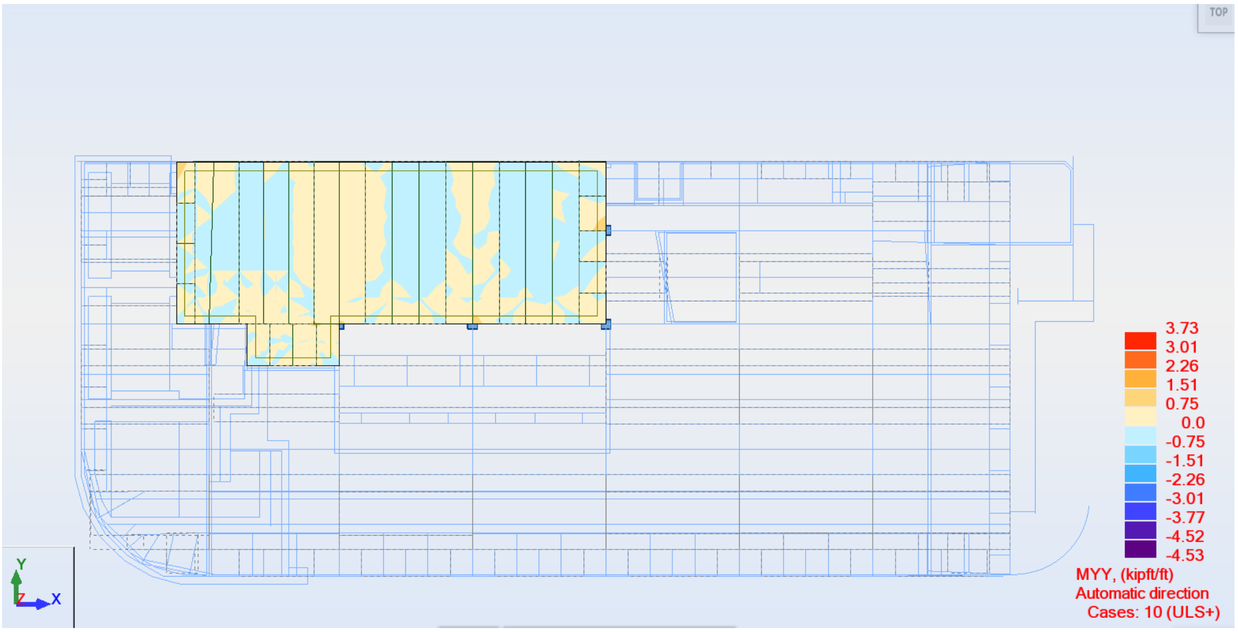


Figure 35: Baseline Model MYY Mechanical Roof

Figure 35 provides the moment distribution on the mechanical roof. The moment of this system is much smaller than the previous diagrams. This is because the live load for the mechanical roof did not include the snowdrift. The distribution of the mechanical roof bays is fairly even and there are no specific areas to be of concern.

Figures 36 and 37 are the moment distribution of floors 2 and 3 with a rectangular foundation. This design was completed, as the team sought to evaluate the complicated geometry of the rounded edge effected the moment distribution. It can be seen in these figures that the columns seem to have an increased moment. The manner in which *Robot* interprets load path and shows the moment distribution does not have much difference than the original foundation analysis. Further, the maps with the square foundation provide the same complications with *Robot* software as the original design. The columns are the area of concern and this seems to be magnified in both Figures 36 and 37.

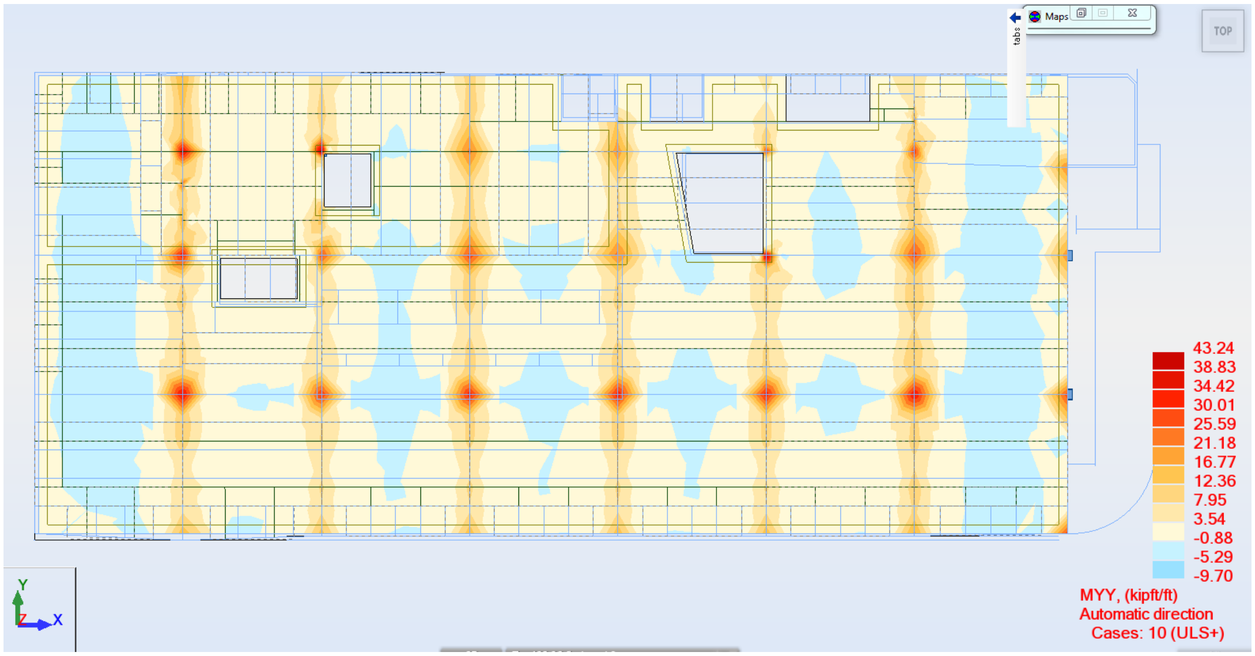


Figure 36: Baseline Model (no curved corner) MYY Floor 2

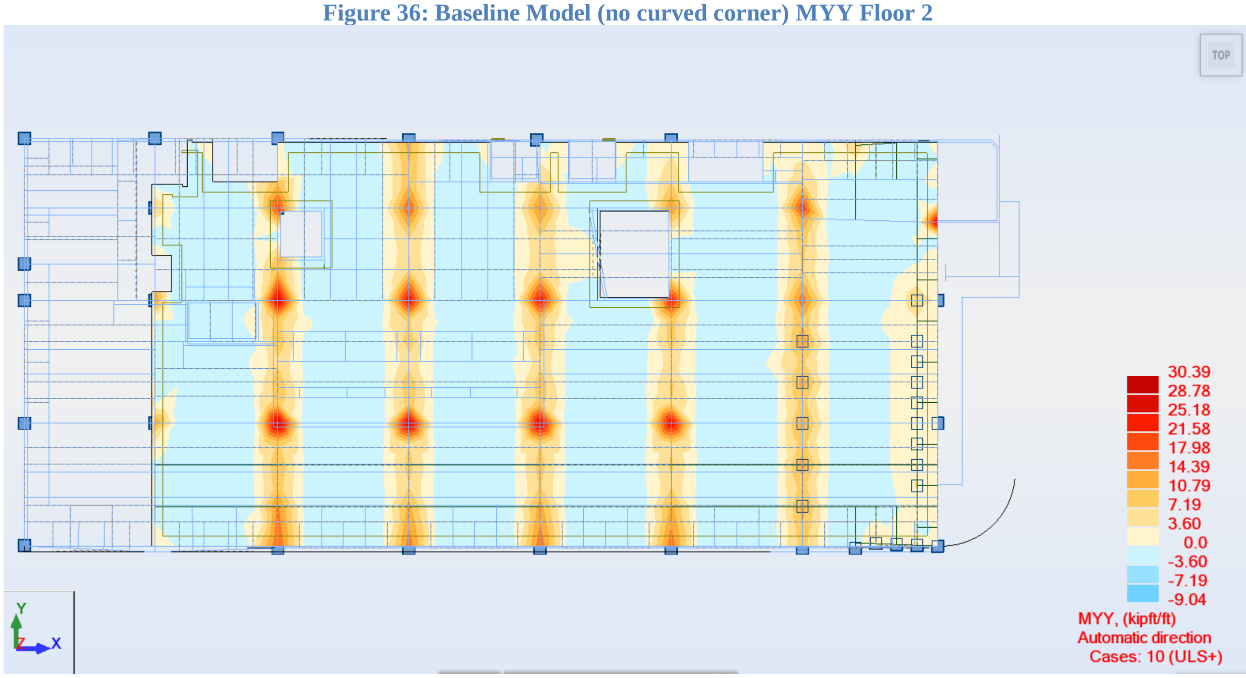


Figure 37: Baseline Model (no curved corner) MYY Floor 3

The baseline model MYY maps provide the team with a means of evaluation of the alternative designs. The model will not be used to determine structural sufficiency; however the models will provide a way of comparison between the moment distributions. For example, the baseline model seems to have a heavy concentration of moment on the columns. This will be compared to the alternative designs in order to provide a conclusion. Further, the team was able to use the baseline model to understand tools and navigation with *Robot* software.

3.5 Cost

After a *Revit* model of the structure was created, a baseline cost was derived. *Revit* automatically calculated the total cubic yards of the concrete involved and the total tonnage of the steel members of the structure. With this information the concrete cost per cubic yard (CY) was formulated using the bid Gilbane had received from the project's subcontractor. In order to do this the cubic yards of all concrete from each area of the building were totaled, and then the bid amount submitted to Gilbane for the overall cost of concrete was divided by the total CY of concrete. Table 3 shows RS Means cost estimates of the project, by section, as well as a comparison of cost between the Bid Package and the RS Means data. (RS Means Construction Cost Data, 2012). These numbers summed to approximately $40,000 less than the bid package Gilbane used, which is an error of 1.6%. A comprehensive breakdown of cost per member can be seen in Appendix L. The RS Means data was used as a learning tool to ensure that accurate costs could be calculated.

Table 3: Baseline Concrete Cost Breakdown

Foundation Wall (CY)	(RS Means)	$912,114.00
Footing (CY)	(RS Means)	$221,888.24
Pilaster (CY)	(RS Means)	$106,336.25
Concrete Slab (CY)	(RS Means)	$619,154.00
Total CY of Concrete		4,236.92
Total Cost of Concrete		$1,859,492.49
Gilbane Bid Package		$1,889,729.00
% error		1.60%
Cost per CY	(RS Means)	$438.88
Cost per CY	(Bid)	$446.01

In order to determine the cost of Structural Steel, the members used in the project were exported from *Revit*. Using RS Means, a cost per ton was tabulated by multiplying the beam length by the unit cost. The RS Means cost estimate included all necessary structural bolts and delivery to the job site (RS Means Construction Cost Data, 2012). Table 4 shows cost per area of work and total cost of steel. This estimate was 2.17% greater than the bid Gilbane had received. A comprehensive breakdown of cost per member can be seen in Appendix M.

Table 4: Baseline Structural Steel Cost Breakdown

Steel Column Cost	(RS Means)	$268,370.84
Steel Framing Cost	(RS Means)	$1,056,755.74
Metal Decking	(RS Means)	$44,436.74
Total Cost of Metal		$1,369,563.31
Gilbane Bid Package		$1,340,500.00
%error		2.17%
Cost per Ton	(RS Means)	$4,883.00
Cost per Ton	(Bid)	$4,779.38

3.6 Schedule

This schedule has been reduced to only show the Concrete and Structural Steel for this project. These two components are the only components that will be affected by a changing floor system, and are the only two analyzed to determine if an alternative floor design would prove more cost or time effective. *Primavera* software was used to build the schedule as well as link the activities together. Table 5 shows important dates for the concrete and steel construction.

Table 5: Important Dates of Construction

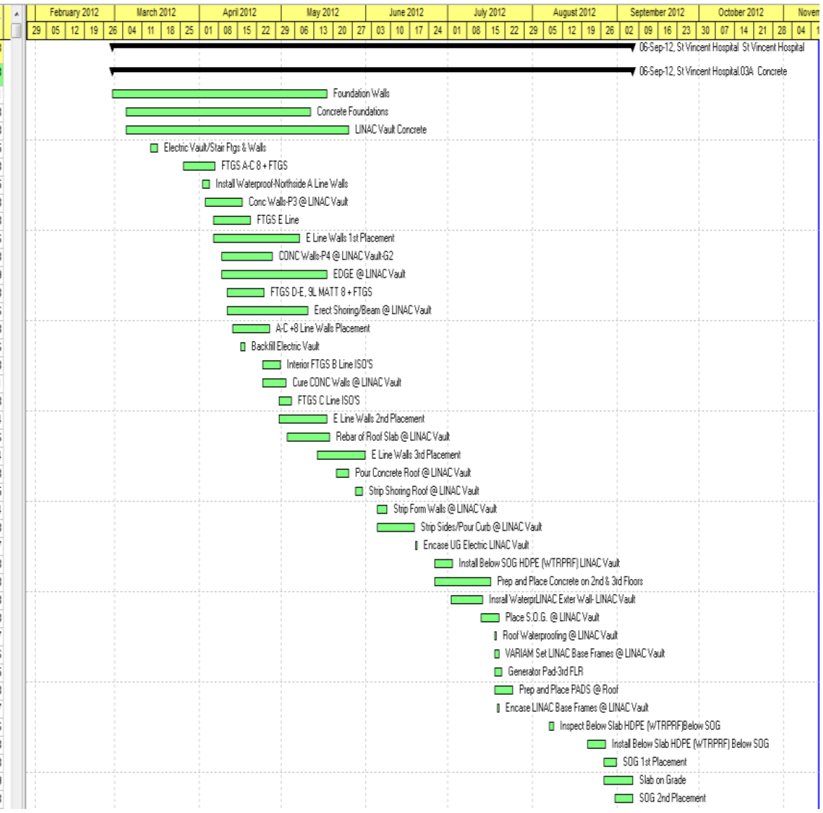
Foundation Complete	17-May-12	All Shop Drawings Submitted	10-Apr-12
Concrete Deck Complete	16-Jul-12	All Shop Drawings Approved	11-Apr-12
Slab on Grade	6-Sep-12	Fabrication and Delivery	12-Jun-12
Concrete Complete	6-Sep-12	Steel Erection Begins	24-May-12
		Steel Erection Finished	12-Jul-12

These dates define the critical path of the early stages of construction, which means that any delay in the execution of these activities will delay the completion of the project. Therefore, in order to complete the project on time the activities along the critical path must be completed on time. One of the first critical objectives is completing the foundation. With this complete the structure can be fully erected above it. Although this is a critical milestone event, some of the related concrete work can be completed as parts of the foundations are completed. Foundation walls can be started after portions of the foundation is finished. With this type of an event starting before the foundation is finished, the time of construction in the schedule is greatly reduced. These events can take place, because the whole foundation is not needed to be fully complete before the other tasks start. During the construction of the foundation and foundation walls, shop drawings for the steel must also be approved. Once these are approved, the steel can start to fabricated, delivered and erected, which is the next critical item on the schedule once the foundation is set. Steel erection includes the setting of columns which must be completed before girders or beams can be set. Once the girders and beams are set, the metal decking can be laid on the framing to complete the structural steel for the project. After this, the critical events are along the concrete schedule, which include slab on deck and slab on grade. Construction of the slab on decks must wait till the framing and decking of each floor is completed because the concrete deck needs the support of these members to set before it has proper strength. The slab on grade cannot be completed before most of the construction on the first floor is completed. This is because heavy machinery is still needed to construct the LINAC (radiation equipment for cancer treatment system) after the building has been constructed, and this machinery could damage the slab on grade. Also, rough-ins such as plumbing and electrical work must be completed. As long as these tasks are completed on time, the project will be able to be completed on time.

This schedule was used as a baseline comparison to determine if there are any time savings with an alternate design. By improving on the critical path, the project can be completed sooner. If one item of the critical path could be improved upon and completed sooner, an impact of starting other critical path items sooner would occur. This would have trickle down effects that could end up finishing the project sooner, or putting other items in to the critical path. A simplified version of Gilbane's schedule can be seen in Figure 38.

In creating a schedule that will effectively promote the completion of the project, many outside factors must be analyzed. This includes the site logistics, which play a crucial role in the construction of the project. Some things that must be taken into account are drop off and storage space, which would have a major effect on the project. Also, the constructability of the project can greatly affect the schedule. This deals with the construction workers' learning curve in dealing with the structure and the ease of construction. These factors must be taken into account when an evaluation of alternatives is conducted.

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
	St Vincent Hospital St Vincer	137	137	0%	29-Feb-12	06-Sep-12	78
	St Vincent Hospital.03A Co	137	137	0%	29-Feb-12	06-Sep-12	78
A1000	Foundation Walls	57	57	100%	29-Feb-12	17-May-12	81
A1010	Concrete Foundations	50	50	100%	05-Mar-12	11-May-12	88
A1020	LINAC Vault Concrete	60	60	100%	05-Mar-12	25-May-12	78
A1030	Electric Vault/Stair Ftgs & W	3	3	100%	14-Mar-12	16-Mar-12	135
A1040	FTGS A-C 8 + FTGS	10	10	100%	26-Mar-12	06-Apr-12	128
A1050	Install Waterproof-Northside	3	3	100%	02-Apr-12	04-Apr-12	135
A1060	Conc Walls-P3 @ LINAC Va	10	10	100%	03-Apr-12	16-Apr-12	128
A1070	FTGS E Line	10	10	100%	06-Apr-12	19-Apr-12	128
A1080	E Line Walls 1st Placement	22	22	100%	06-Apr-12	07-May-12	116
A1090	CONC Walls-P4 @ LINAC V	15	15	100%	09-Apr-12	27-Apr-12	123
A1100	EDGE @ LINAC Vault	29	29	100%	09-Apr-12	17-May-12	109
A1110	FTGS D-E, 9L MATT 8 + FT	10	10	100%	11-Apr-12	24-Apr-12	128
A1120	Erect Shoring/Beam @ LIN	22	22	100%	11-Apr-12	10-May-12	116
A1130	A-C +8 Line Walls Placemer	10	10	100%	13-Apr-12	26-Apr-12	128
A1140	Backfill Electric Vault	2	2	100%	16-Apr-12	17-Apr-12	136
A1150	Interior FTGS B Line ISO'S	5	5	100%	24-Apr-12	30-Apr-12	133
A1160	Cure CONC Walls @ LINAC	7	7	100%	24-Apr-12	02-May-12	131
A1180	FTGS C Line ISO'S	5	5	100%	30-Apr-12	04-May-12	133
A1170	E Line Walls 2nd Placement	14	14	100%	30-Apr-12	17-May-12	124
A1190	Rebar of Roof Slab @ LINA	12	12	100%	03-May-12	18-May-12	126
A1200	E Line Walls 3rd Placement	14	14	100%	14-May-12	31-May-12	124
A1210	Pour Concrete Roof @ LIN	5	5	100%	21-May-12	25-May-12	133
A1220	Strip Shoring Roof @ LINAC	3	3	100%	28-May-12	30-May-12	135
A1230	Strip Form Walls @ LINAC V	4	4	100%	05-Jun-12	08-Jun-12	134
A1240	Strip Sides/Pour Curb @ LIN	10	10	100%	05-Jun-12	18-Jun-12	128
A1250	Encase UG Electric LINAC V	1	1	100%	19-Jun-12	19-Jun-12	137
A1260	Install Below SOG HDPE (W	5	5	100%	26-Jun-12	02-Jul-12	133
A1270	Prep and Place Concrete or	15	15	100%	26-Jun-12	16-Jul-12	123
A1280	Insrall WaterprLINAC Exter V	10	10	100%	02-Jul-12	13-Jul-12	128
A1290	Place S.O.G. @ LINAC Vau	5	5	100%	13-Jul-12	19-Jul-12	133
A1300	Roof Waterproofing @ LIN	1	1	100%	18-Jul-12	18-Jul-12	137
A1340	VARIAM Set LINAC Base Fr	2	2	100%	18-Jul-12	19-Jul-12	136
A1310	Generator Pad-3rd FLR	3	3	100%	18-Jul-12	20-Jul-12	135
A1320	Prep and Place PADS @ R	5	5	100%	18-Jul-12	24-Jul-12	133
A1350	Encase LINAC Base Frames	1	1	100%	19-Jul-12	19-Jul-12	137
A1360	Inspect Below Slab HDPE (	2	2	100%	07-Aug-12	08-Aug-12	136
A1370	Install Below Slab HDPE (W	5	5	100%	21-Aug-12	27-Aug-12	133
A1380	SOG 1st Placement	5	5	100%	27-Aug-12	31-Aug-12	133
A1390	Slab on Grade	9	9	100%	27-Aug-12	06-Sep-12	129
A1400	SOG 2nd Placement	5	5	100%	31-Aug-12	06-Sep-12	133



Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
	St Vincent Hospital St Vincer	137	137	0%	29-Feb-12	06-Sep-12	78
	St Vincent Hospital.03A Co	137	137	0%	29-Feb-12	06-Sep-12	78
	St Vincent Hospital.05A Str	92	92	0%	07-Mar-12	12-Jul-12	83
A1410	Prep/SBMT Shop Drawings	22	22	100%	07-Mar-12	05-Apr-12	106
A1420	R/A Submittals Metal Stairs	10	10	100%	03-Apr-12	16-Apr-12	71
A1430	RVW/APPRV Shop Drawin	5	5	100%	04-Apr-12	10-Apr-12	43
A1440	Prep/SBMT Shop Drawings	2	2	100%	06-Apr-12	09-Apr-12	91
A1450	RVW/APPRV Shop Drawin	10	10	100%	06-Apr-12	19-Apr-12	38
A1460	R/A Submittals Metal Stairs	10	10	100%	06-Apr-12	19-Apr-12	81
A1470	P/S Submittals Metal Railing	15	15	100%	06-Apr-12	26-Apr-12	83
A1480	FAB/Deliver Steel Framing D	40	40	100%	06-Apr-12	31-May-12	88
A1490	RVW/APPRV Shop Drawin	10	10	100%	09-Apr-12	20-Apr-12	106
A1500	Prep/SBMT Shop Drawings	1	1	100%	10-Apr-12	10-Apr-12	96
A1510	RVW/APPRV Shop Drawin	5	5	100%	10-Apr-12	16-Apr-12	91
A1520	RVW/APPRV Shop Drawin	1	1	100%	11-Apr-12	11-Apr-12	96
A1530	FAB/Deliver Steel Framing D	29	29	100%	13-Apr-12	23-May-12	38
A1540	FAB/Deliver Steel Framing D	40	40	100%	17-Apr-12	11-Jun-12	88
A1550	FAB/Deliver Steel Framing D	40	40	100%	18-Apr-12	12-Jun-12	88
A1560	FAB/Deliver Steel Framing	24	24	100%	20-Apr-12	23-May-12	53
A1570	FAB/Deliver Metal Stairs C	30	30	100%	20-Apr-12	31-May-12	71
A1580	FAB/Deliver Metal Stairs B	30	30	100%	20-Apr-12	31-May-12	81
A1590	FAB/Deliver STR Steel Der	23	23	100%	23-Apr-12	23-May-12	54
A1600	R/A Submittals Metal Railing	10	10	100%	27-Apr-12	10-May-12	83
A1610	FAB/Deliver Metal Railings	30	30	100%	11-May-12	21-Jun-12	83
A1660	Mezanine Steel Columns	13	13	100%	24-May-12	11-Jun-12	
A1620	Structural Steel Erection	0	0	100%	24-May-12		
A1710	Mezanine Framing	4	4	100%	11-Jun-12	14-Jun-12	
A1720	2nd and 3rd Floor Framing a	3	3	100%	14-Jun-12	18-Jun-12	
A1650	Steel Detailing	20	20	100%	15-Jun-12	12-Jul-12	110
A1730	Other Steel Columns	2	2	100%	18-Jun-12	19-Jun-12	
A1740	Other 2nd and 3rd Floor Fra	3	3	100%	19-Jun-12	21-Jun-12	
A1770	Roof Framing	8	8	100%	20-Jun-12	29-Jun-12	
A1760	2nd and 3rd Floor Metal Dec	5	5	100%	21-Jun-12	27-Jun-12	
A1780	Mezanine Metal Decking	6	6	100%	05-Jul-12	12-Jul-12	
A1790	Roof Metal Decking	6	6	100%	05-Jul-12	12-Jul-12	
A1630	Structural Steel Erection	0	0	100%		12-Jul-12	

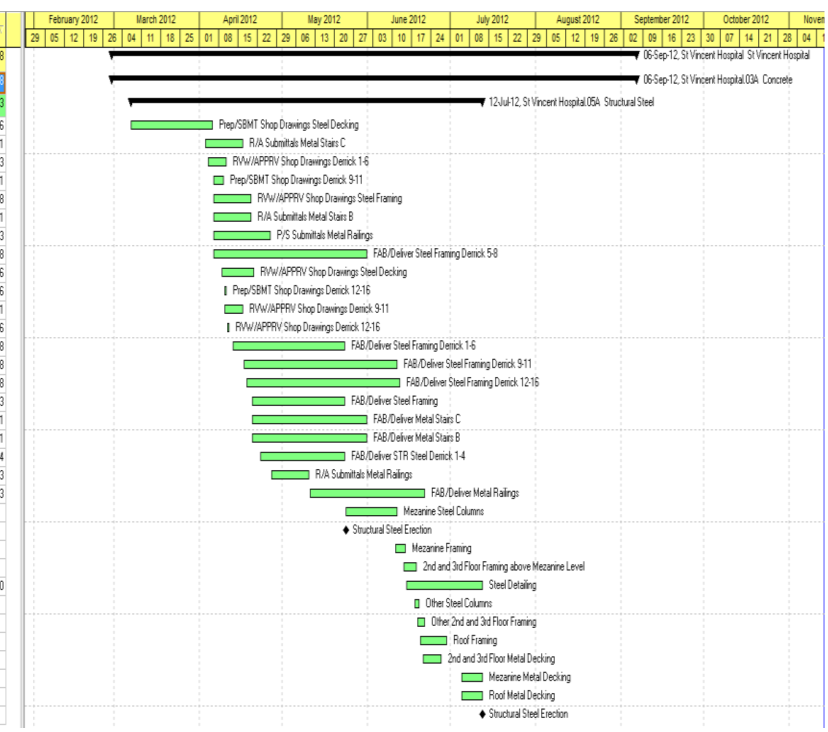


Figure 38: Baseline Schedule for Foundation and Superstructure (Gilbane)

3.7 Site Plan

Jobsite organization is essential for a productive construction project (Mincks, Johnston, 1998). Bad flow and efficiency on a jobsite can lead to behind schedules and over drafted budgets. There are many different variables to consider when developing a site plan, those being; jobsite space allocation, jobsite access, material handling, worker transportation, temporary facilities, jobsite security, and signage and barricades. When creating the site plan for the St. Vincent Cancer Center project there were many space constraints that were taken into consideration. Traffic flow around the site was primarily determined on the fact that the site was located on a one way street in busy downtown Worcester. Consigli Construction is vacating a larger site directly behind the Cancer Center’s site creating a space constraint for the Gilbane team.

With this knowledge, it was determined that the site should primarily be a drop-off and install system to increase site flow, and a location on the northeast side of the site was designated for a drop off only area, as shown in Figure 39 below. There is also a material and equipment storage area on the southwest side of the site. This area is only meant for smaller equipment and materials of construction like soil compactors, concrete materials, wire ties, wire mesh, etc. Although these areas are described as diametrically opposed from each other, they are actually only separated by the one road used for site transportation, as shown in Figure 39. Site security consists of construction fence and entrance/exit gates at south and north locations of the site. Emergency egress locations were placed at the north and east side of the site. Cranes and other heavy equipment are located based on the progress of the project. Finally, portable restrooms were placed on the south side of the site parallel to Foster Street.

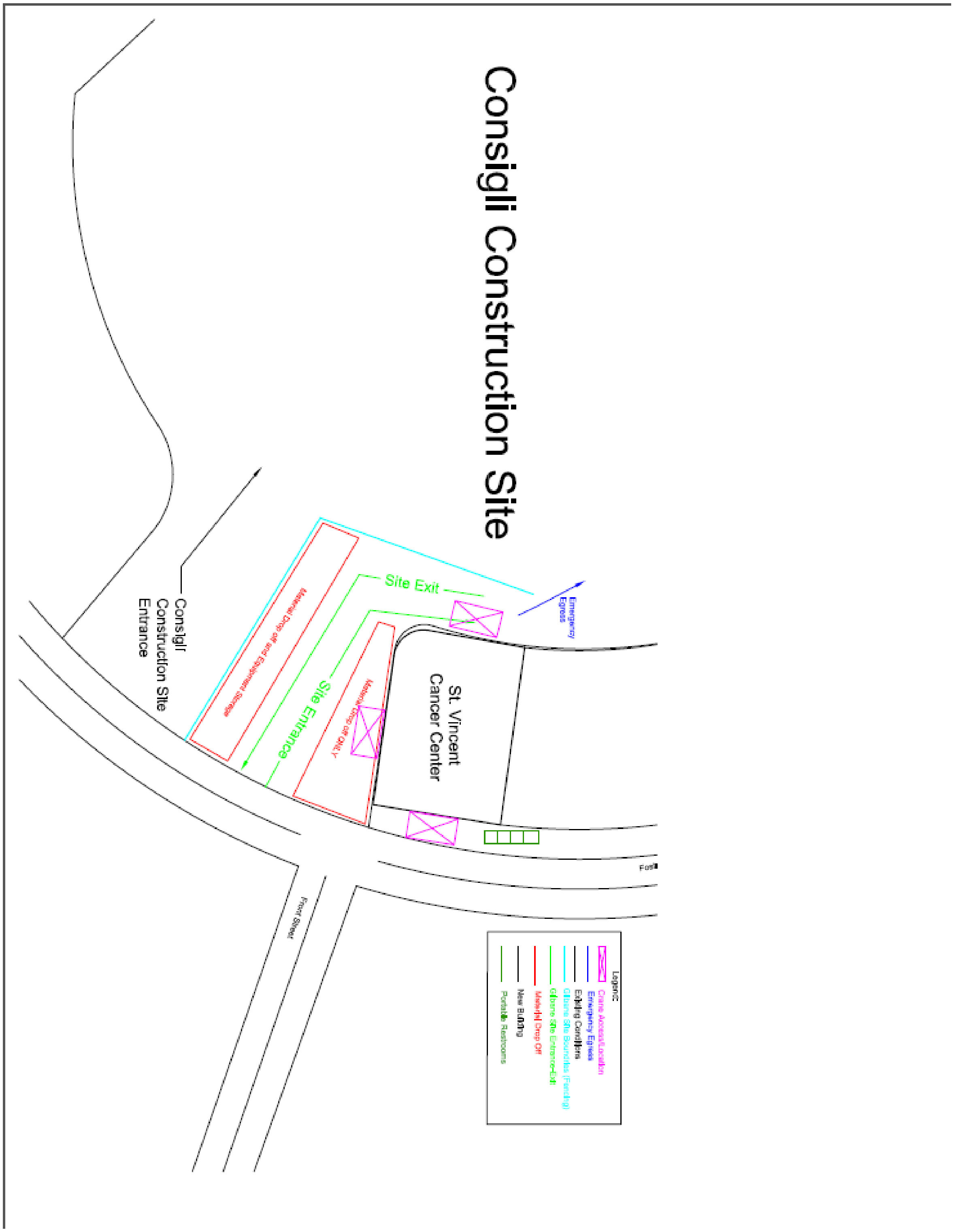


Figure 39: Site Plan

Ideally there would be more storage area to minimize possible scheduling issues. For example, with the project being on a drop off and install system, the schedule relies on subcontractors and delivery. If the site were to have more storage area, the efficiency of the schedule would rely on the construction team. The site plan maximizes site flow while also ensuring site safety, which are ideal variables for any construction site

Another major constraint that was considered while determining the site plan was the close proximity to the existing parking garage, and the implementation of the building separation joint. Building separation joints are a standard requirement for all buildings that are built within close proximity of each other. The building separation joint separating the existing parking garage and the Cancer Center can be seen in Figure 40 and Figure 41. Some requirements when building the separation joint include ensuring adequate footing reinforcement of the existing parking garage. Excess stress, which is usually supported by the surrounding soil, can be endured by the parking structure when removing soil away from the parking garage footing. In order to account for this stress and possible displacement, footing reinforcement methods were utilized. One method that is typically utilized is installing rebar on a calculated angle through the existing footing and into the ground beneath the footing. Although this constraint only lasted a couple of weeks compared to the rest of the project, it posed a high safety risk for both the laborers and the parking garage foundation stability.

Figure 40: Exterior view of building separation joint

Figure 41: Interior view of building separation joint.

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4.0 Floor System with Open-Web Bar Joists

Once the benchmark analysis was completed, the first alternative floor system design to the St. Vincent Hospital building could be started. In order to accurately design a system with open-web bar joists, research on methods of design and the limits to open-web bar joists was completed. The baseline *Revit* model was adjusted with the new open-web bar joist design and reanalyzed. Following the structural analysis, a cost estimate and schedule were made to explore any differences with the baseline.

4.1 Design of Bays

Open-web bar joists are unique in the fact that they are designed by a number of joist manufacturers. The Steel Joist Institute (SJI) is a United States based nonprofit organization of active joist manufacturers used to address the lack of uniform joist standards for the industry (*Steel Joist Institute*, 2010). SJI also offers seminars and a library of training and research aids. After looking into the information offered by the SJI a manufacturer of the steel needed to be chosen, as the bar joists are unique to their manufacturer. The major manufacturers of the joists that are recognized by SJI are Nucor Vulcraft, Canam Steel Corp, and SMI Joist Company *(Delhi University*). The team decided to refer to Nucor Vulcraft Group information in the design of the joist floor system as they have a number of catalogues available online.

A major advantage of using Vulcraft was that they offer multiple catalogues for the different types of steel products that they manufacture. The three main catalogues utilized were the Composite and Non-composite Joists, Steel Joists and Girders, and Steel Roof and Floor Deck. Using the steel deck catalogue a dead weight for the 20 gage steel and normal weight concrete slab was found to be 63 pounds square foot ("Vulcraft steel deck," 2008). This number would be carried throughout the design of the floor systems. The catalogue was also used to determine the weight of the steel deck for input to calculation of the roof dead load. The other design loads to be used in the selection of the open-web bar joists would be the building's service live loads, snow loads, and snowdrift loads. All other loads were neglected, as they do not have a major effect on the design and performance of the floor systems.

The design of the floor system consisted of K series standard joists that range from 8 inches to 30 inches in depth (Ching, 2008). The first step in the design of the joists is determining what size joist to use. To do so the spacing between the joists is determined so that the joists will satisfy the magnitude of the floor load over a given span. The spacing can range from 2 feet to 10 feet (Ching, 2008). Furthermore, the joists spans are limited to 24 times their depth. The spacing of the joists used in our design was the maximum possible spacing for a joist spanning a given distance in order to minimize the number of joists. Figure 42 below shows K series joists and the different types of bridging.

It is important to verify that the steel decking can accommodate the newly designed joist spacing for both the decking and the slab. The Vulcraft Steel Deck catalogue provides alternative live load information for reinforced concrete slabs. It can be seen in the catalogue that for the 20 gage galvanized steel decking the capacity increases as the clear span between beams decrease. Verification was made that the steel decking was sufficient for the 10 foot clear spans in the baseline model; therefore the decking is sufficient for the smaller designed spacing for the joists as seen in on page 66 of this report. The spacing of the joists is an average of around 3 feet, so the 20 gage steel would easily maintain structural integrity, and a lighter steel decking may be capable of supporting the loads at a 3 foot span. However, for the design of this system the 20 gage steel decking will be used in the structural analysis.

After determining the spacing of the joist the next step was selecting the joist to be used. This was done by listing the possible joists that met the load criteria at a proposed spacing and choosing the lightest option. The Vulcraft catalogue was used to find the possible joists over a given span. For a given joist size, the catalogue shows a maximum total load of the joist in black and a maximum live load in red, as a function of the span which can be seen below in Figure 42.

ASD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown in Pounds per Linear Foot (plf)

Joist Designation	28K6	28K7	28K8	28K9	28K10	28K12	30K7	30K8	30K9	30K10	30K11	30K12
Depth (In.)	28	28	28	28	28	28	30	30	30	30	30	30
Approx. Wt. (lbs./ft.)	11.4	11.8	12.7	13.0	14.3	17.1	12.3	13.2	13.4	15.0	16.4	17.6
Span (ft.) ↓												
28	548 541	550 543	550 543	550 543	550 543	550 543						
29	511 486	550 522	550 522	550 522	550 522	550 522						
30	477 439	531 486	550 500	550 500	550 500	550 500	550 543	550 543	550 543	550 543	550 543	550 543
31	446 397	497 440	550 480	550 480	550 480	550 480	534 508	550 520	550 520	550 520	550 520	550 520
32	418	466	515	549	549	549	501	549	549	549	549	549

Figure 42: Standard Load Table for Open Web Steel Joists, K Series

For rectangular bays it is best to orient the joists to span in the short direction for strength (*Lecture 18-open web*). The design of a 32-foot by 30-foot bay was used to review this guideline. This was chosen, as the width and length of the bays are fairly similar, and the orientation proves to be more efficient in the short spanning direction, it will only be magnified in a bay that has a greater difference in length and width. In the trial, the joists were oriented each way, and it was found that the lightest and most economical system was indeed for the joists spanning in the shorter direction. For all other designs the spanning direction was carried out in each bay design, and a bar joist was chosen for each bay as seen in Figures 44, 45, 46, and 47. Figure 43 below is a summary of all of the open-web joist designs for the bay systems of the building. The column outside the figure shows the reference page in Appendix K: Open-Web Bar Joist Hand Calculations for review of the supporting calculations.

Bay Area	Live Load	Proposed Bar Joist	Weight (lb/ft)	Span Length (ft)	Spacing (ft)	Number of Joists	Lbs of Steel Joists	Reference Page
32x30	100	24k9	12	30	3.2	9	3240	3
32x22.5	100	22K4	8	22.5	3.2	9	1620	5
30x30	100	28k7	11.8	30	3	9	3186	6
28x30	100	28k7	11.8	30	3.11	8	2832	7
28x20	100	16k5	7.5	20	3.11	8	1200	8
32x16.33	100	16k2	5.5	16.33	3.2	9	808.335	9
32x20	100	24k9	12	30	3.2	9	3240	11
33X30	100	26k9	12.2	30	3.3	9	3294	10
33X22.5	100	22k5	8.8	22.5	3.3	9	1782	10
33X20	100	18k4	7.2	20	3.3	9	1296	11
30x20	100	18k4	7.2	20	3.3	8	1152	12
30x32	127.75	30k7	12.3	30	4	7	2583	1
24X33	127.75	24k5	9.3	24	4.125	7	1562.4	1
30X33	127.75	30k7	12.3	30	4.125	7	2583	2
20X33	127.75	20k4	7.6	20	4.125	7	1064	2
22.5X32	127.75	22k5	8.8	22.5	4	7	1386	3
32X24	127.75	24k5	9.3	24	4	7	1562.4	3
31X30	127.75	26k9	12.2	30	2.82	10	3660	4
38.83x32	38.5	28k7	11.8	32	9.71	3	1132.8	5
38.83x30	38.5	26k6	10.6	30	9.71	3	954	5
							0	
							0	
Roof Lbs of Open-Web Bar Joists							14400.8	
1st and 2nd Floors Lbs of Open-Web Bar Joists							23650.335	
Total Weight of Proposed Open-Web Bar Joists							40137.935	

Figure 43: Proposed Open-Web Bar Joists

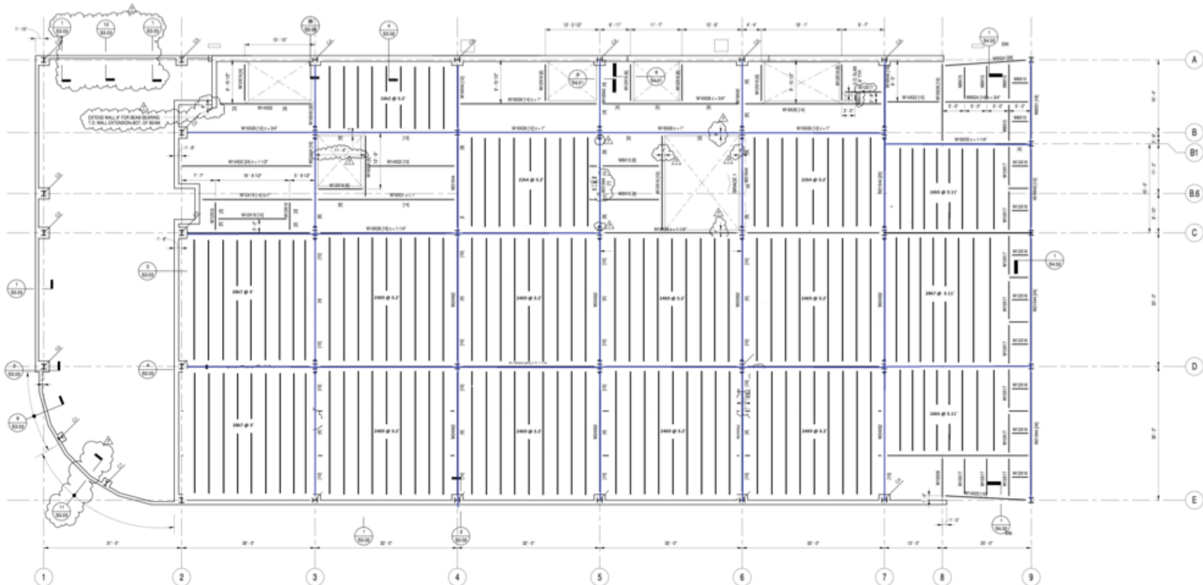


Figure 44: 2nd Floor Layout of Open-Web Bar Joists

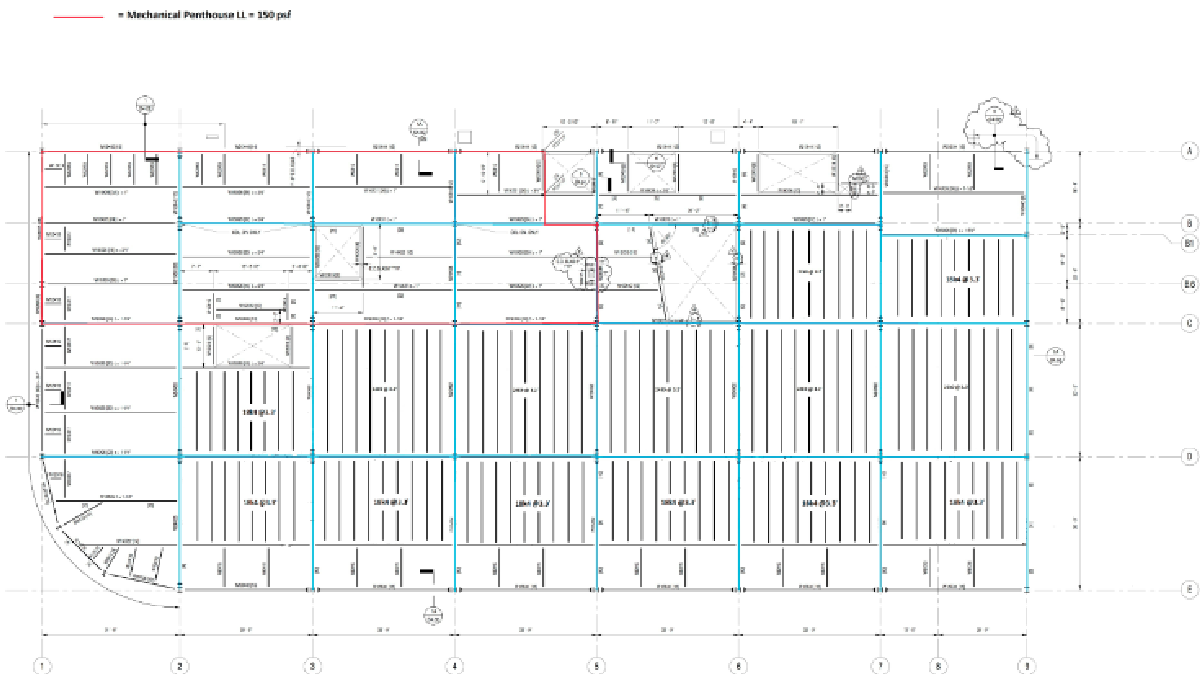


Figure 45: 3nd Floor Layout of Open-Web Bar Joists

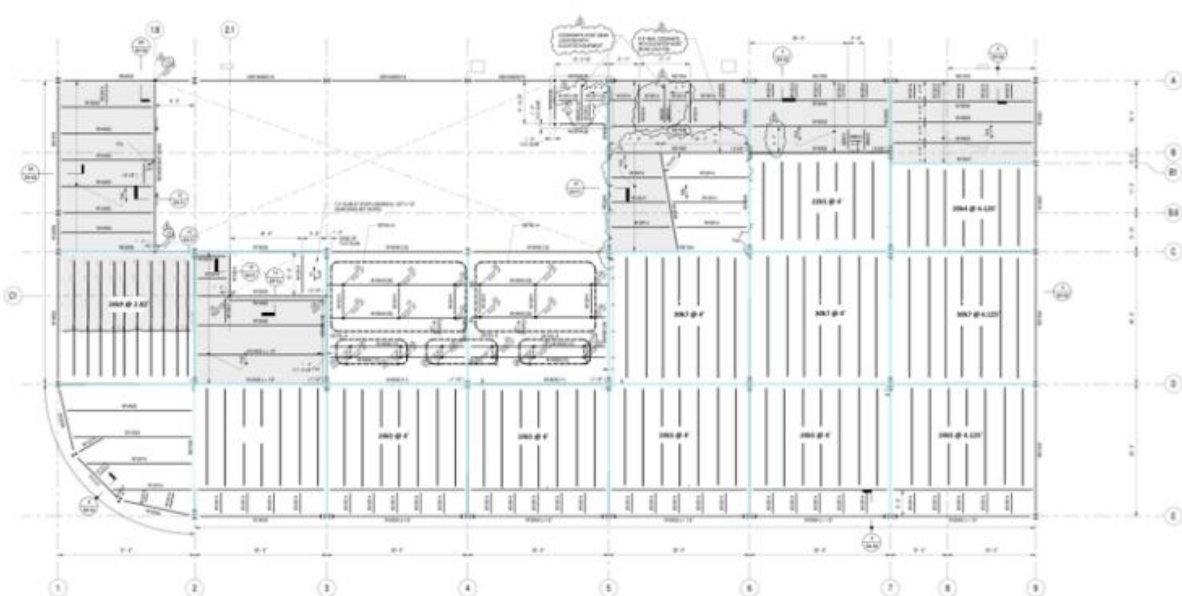


Figure 46: Roof Layout of Open-Web Bar Joists

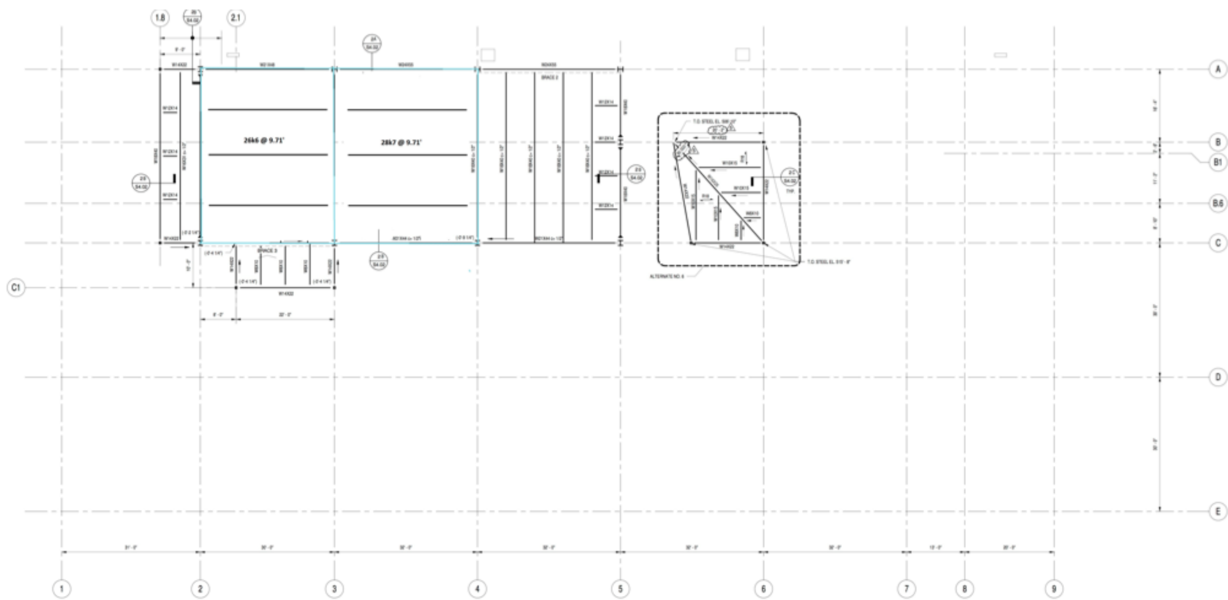


Figure 47: Mechanical Roof Layout of Open-Web Bar Joists

It can be seen in the figures above and for the design of the open web joist system that some bays do not have open-web bar joists. Not all bays in the building are rectangular; therefore the baseline I-beam system was kept in place. There are many openings in the floor systems for ductwork, elevators, stairs, etc. that provide complications in the design. Also the building has a rounded edge that provides further complications in designing open-web bar joists. These bays were also not redesigned, and the original beam designs were replicated. The entire design of the floor system would most likely be redesigned if the building were to have an open-web joist floor system. The intent of this project is to evaluate the differences between the open-web joists and the I-beam floor system using the same initial design that is in place at the St. Vincent Cancer Center.

Another important factor for the design of open-web bar joists is horizontal or diagonal bridging to prevent lateral movement of joist chords (Ching, 2008). Bridging can be seen below in Figure 48. Bridging was designed using Vulcraft catalogues that specify bridging requirements. This was not completed for all of the bays however, as it is not necessary in the scope of the analysis in the *Revit* and *Robot* model. The importance of bridging in open-web bar joist systems should be noted and properly specified as part of the complete structural design.

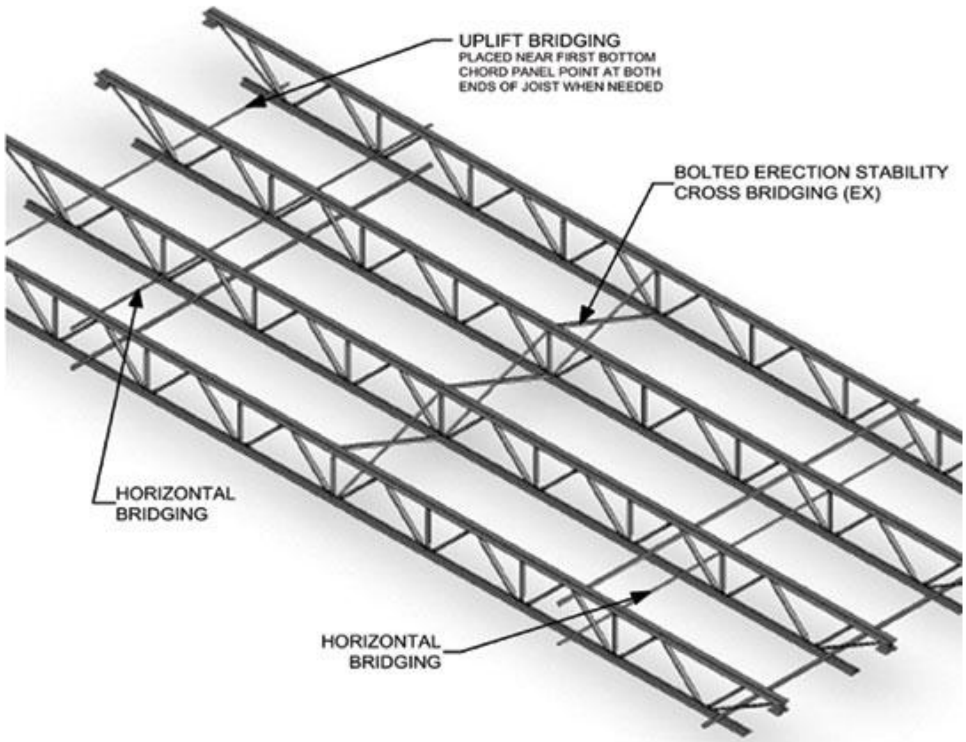


Figure 48: Open-Web Bar Joists and Bridging

For constructability purposes another alternative design was evaluated. The variety of joist sizes was reduced in the bays. To do so the Vulcraft Bar Joist Catalogue was used to select a bar joist that meets the design loads and reduces the number of joist sizes per floor. This system provides an overdesign in structural aspects of the building and will be evaluated for its impact on schedule and cost. The same joist were used for all the bays that were similar in size, however as referenced in Figure 42, the load tables provide limits for spanning that is dependent on the joist designation.

4.2 *Revit* Model

Using the design drawings created from the hand calculations, the *Revit* model for the first alternative structure was created. A duplicate of the baseline model was used, and certain beams were deleted as a first step to defining the proposed open-web bar joist bays. The beam-system tool was utilized to expedite the modeling process. Because the layout adopted for the open-web bar joists was extremely similar to that of the baseline, the updated model was prepared rather quickly. Two *Revit* renderings showing the open-web bar joist alternative are shown in Figure 49 below.

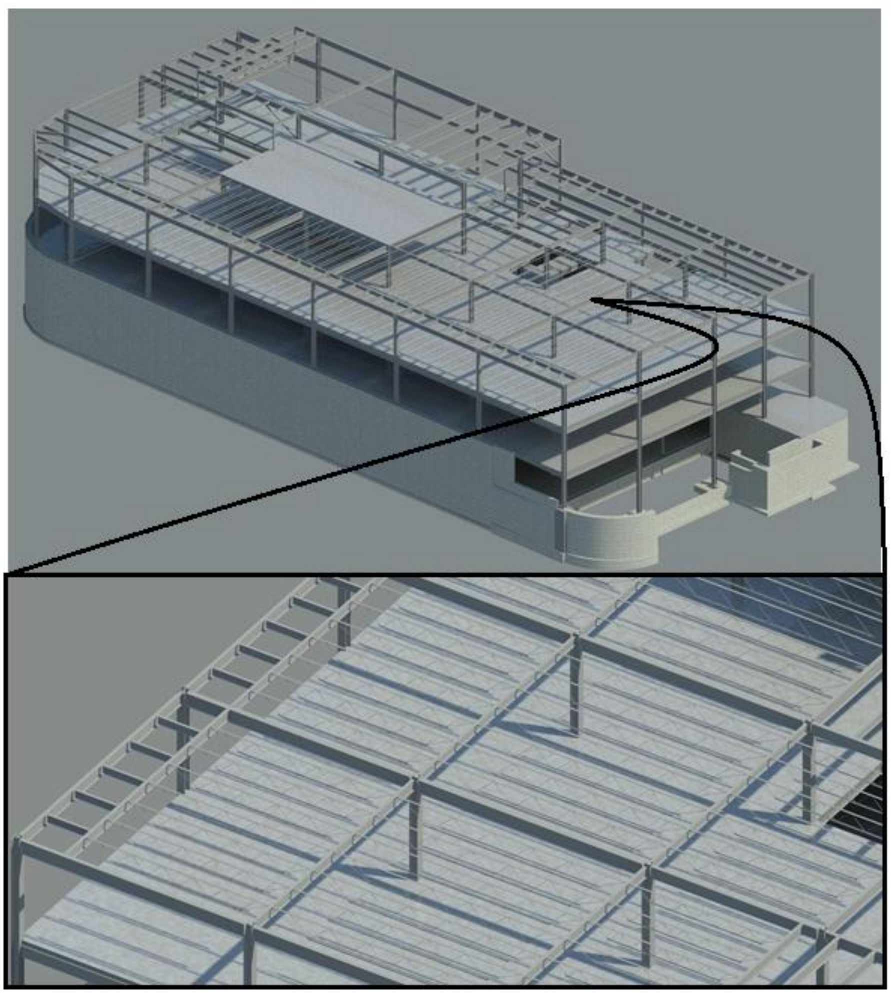


Figure 49: Open-Web Bar Joist Model Rendering

4.3 *Robot* Analysis

As the open-web bar joist model was exported to *Robot*, warnings and errors similar to those generated by the baseline model were expected. There was only one issue on the initial export: a section of the model had open-web bar joists in a bay that did not satisfy minimum beam requirements. A screenshot of the error can be seen in Figure 50.

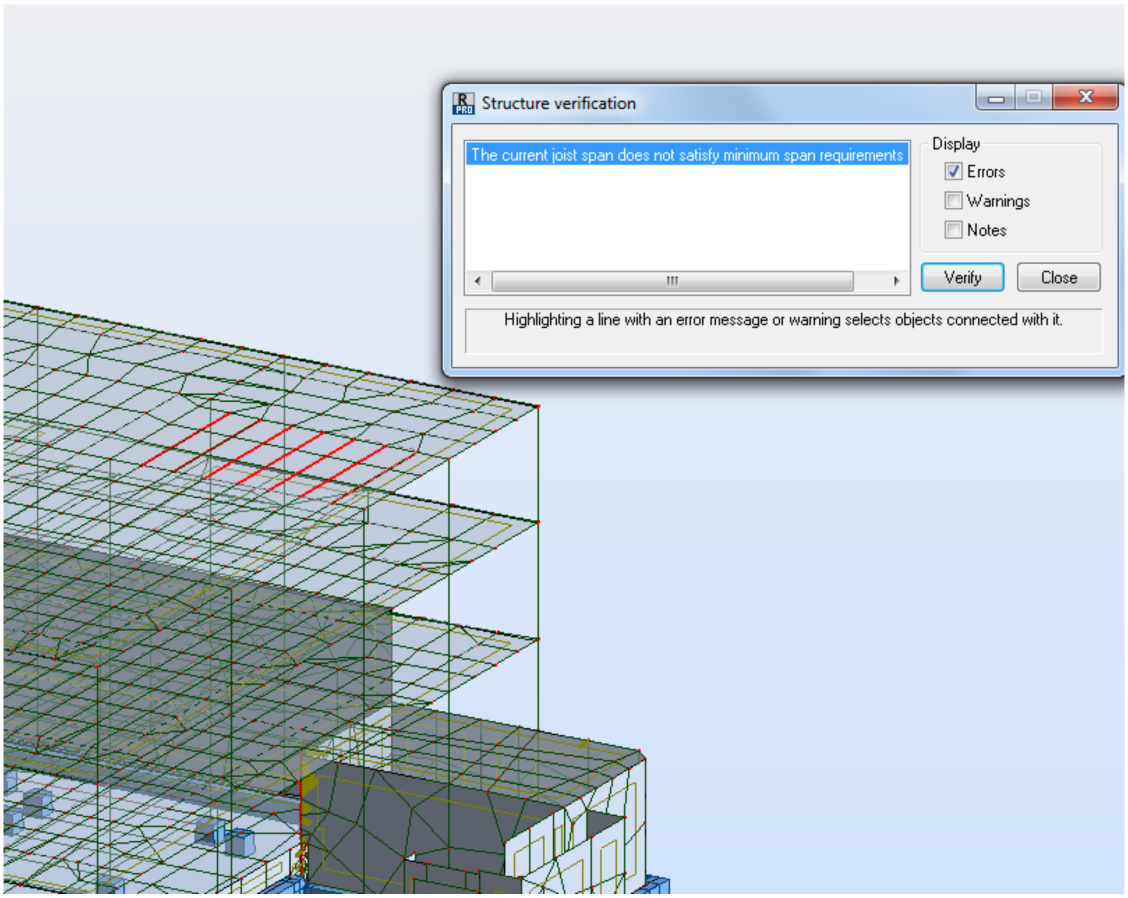


Figure 50: Open-Web Bar Joist Model *Robot* Analysis Error

This error prevented the software from making any calculations, similar to the FE mesh problem. The minimum span of the open-web bar joist used, 20K4, is 20 feet. While the span gridline-to-gridline is 20 feet, one also has to also consider that the flange of the W-shape protrudes slightly on either side of the gridline. This means the actual span of the joist is slightly less than 20 feet, and a 20K4 joist cannot be used. Therefore, the 20K4 joists were replaced with

18K10 joists, which met the span requirements and were the lightest selection of joists to meet the live load requirements. After this change was made in *Revit*, the *Robot* software was able to begin its computations.

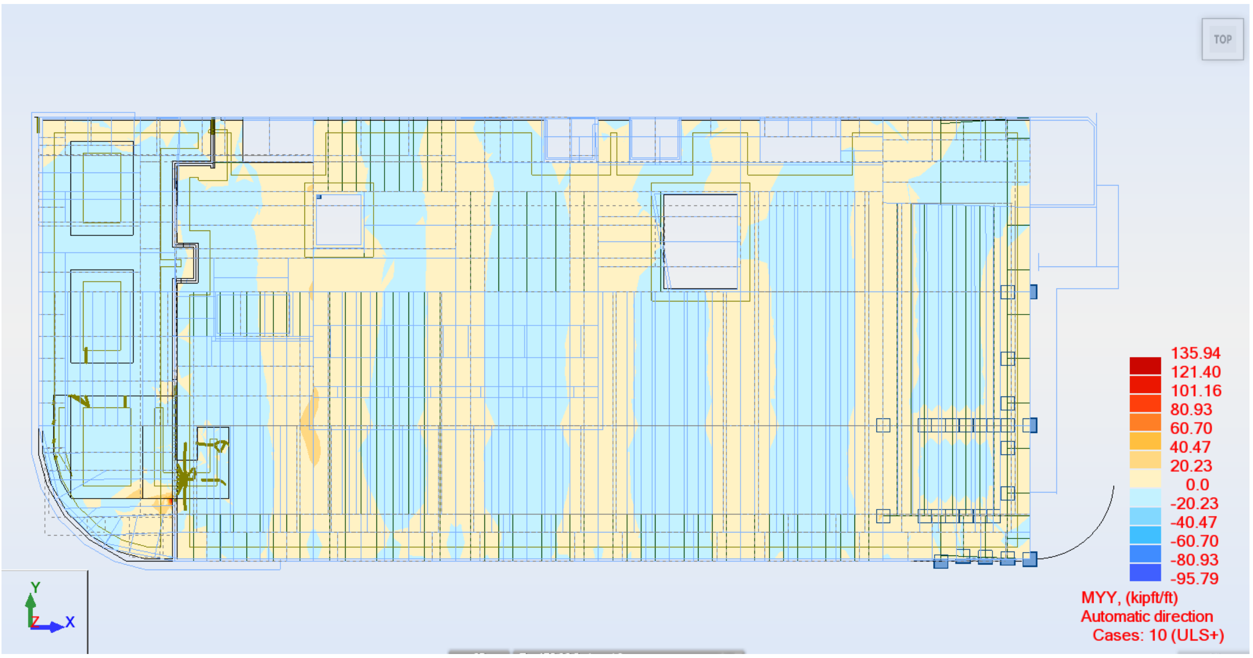


Figure 51: Open-Web Bar Joists Level 2 MYY Map

Figure 51 above shows the moment distribution of Level 2 with the proposed open-web bar joist design. The moment for the floor is evenly distributed. There does not seem to be any areas of concern or concentrated moment. The moment is similar in the y-axis and differs in the x-axis.

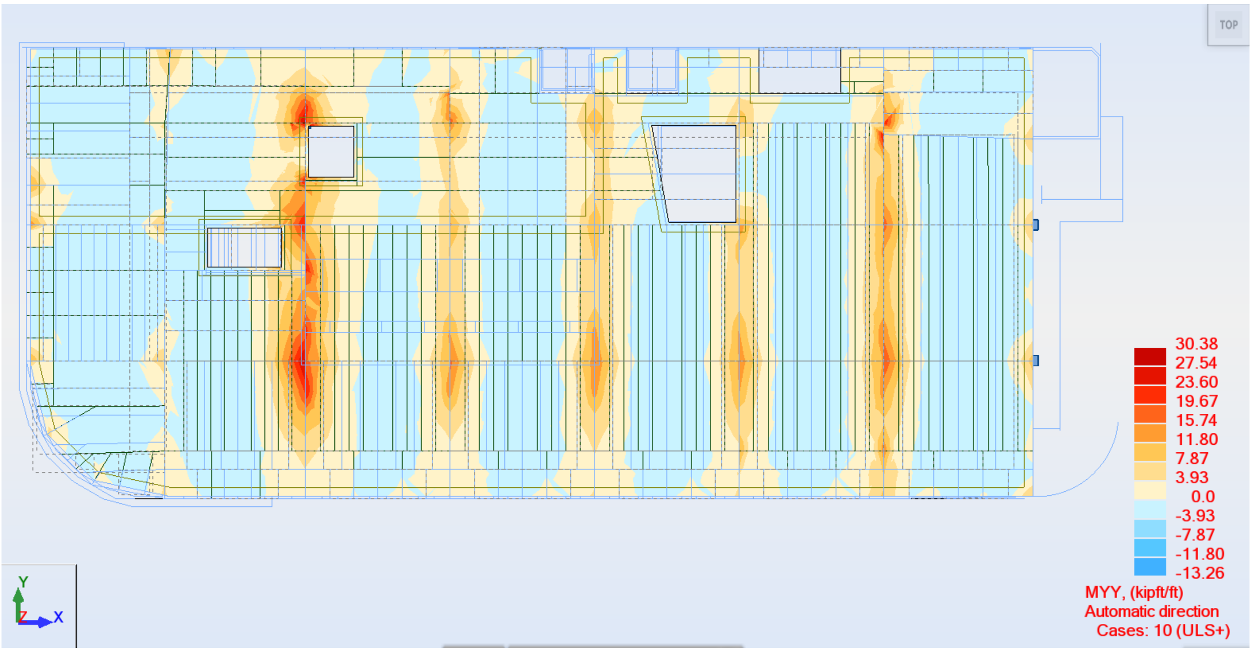


Figure 52: Open-Web Bar Joists Level 3 MYY Map

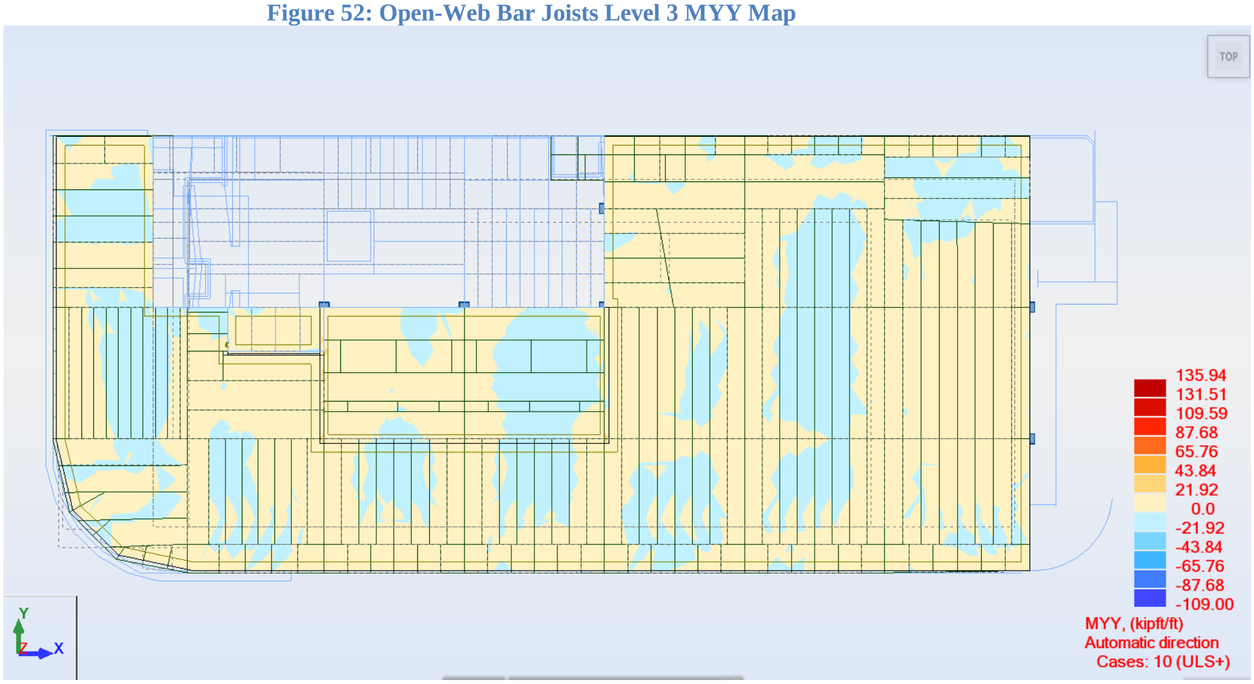


Figure 53: Open-Web Bar Joists Roof MYY Map

Figure 52 shows the moment distribution on floor three with open-web bar joists. The moment seems to be highest at the column lines in the y-axis. The scale on this moment diagram is different than that of Figure 49, therefore the areas of heavy loading seem to be of greater magnitude, but may not necessarily be. By using a smaller scale, Figure 50 displays the concentration of moment more in more detail.

Figure 53 provides a different moment distribution pattern than the previous two MYY Maps of floor 2 and 3. This figure uses a larger scale than Figure 50, so the magnitude of the concentrations is not as highlighted.   It can be seen that some bays have little or no negative moment in them.

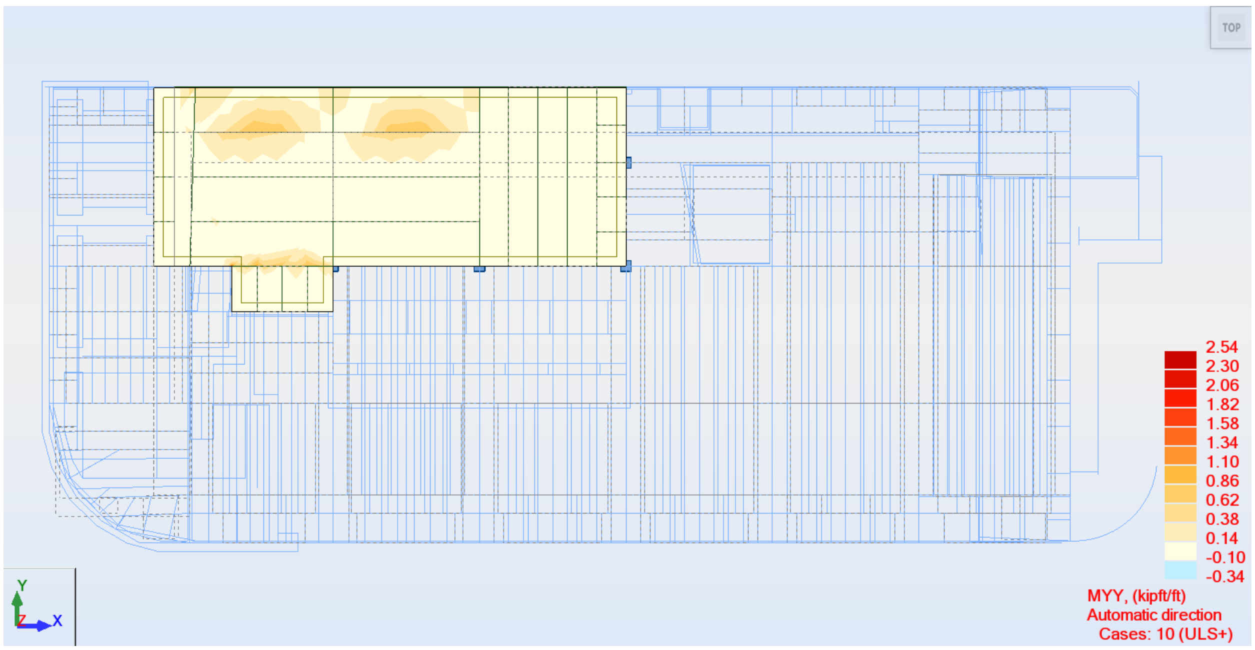


Figure 54: Open-Web Bar Joists Mechanical Roof MYY Map

The mechanical roof system has a very small magnitude of moment displayed in the moment map in Figure 54. The moment for all bays is positive, which has not occurred in any previous moment diagrams.

4.4 Cost

Once a *Revit* model with open-web bar joists was created, an RS Means cost estimate was prepared. This estimate was put together by replacing most bays with open-web bar joists, while retaining W-shape sections for girders and high loaded bays such as areas with elevators and stair cases. Steel framing was the only component of steel that was changed by using open-web bar joists. Table 6 below shows cost estimations using unit cost data from RS Means. The RS Means estimates include all necessary structural bolts, delivery to the job site, and bracing (*RS Means Construction Cost Data*, 2012). A comprehensive breakdown of cost per member of the steel framing can be seen in Appendix N.

Table 6: Open-Web Bar Joists Steel Costs

Steel Column Cost			$268,370.84
Steel Framing Cost			$1,028,047.12
Metal Decking			$44,436.74
Total Cost of Metal			$1,340,854.69
Cost per Ton			$4,658.06

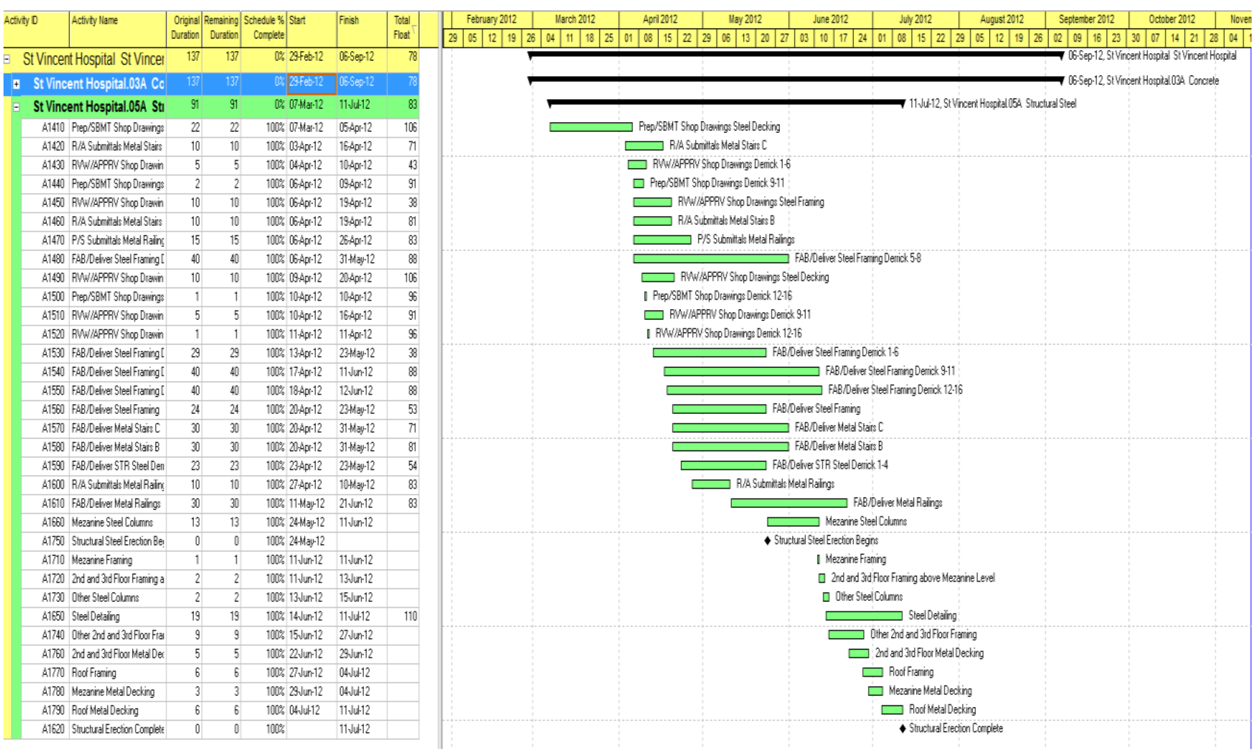
In order to improve constructability a second open-web bar joist design was created. This design used more uniform open-web joists to have a more constant construction plan. By reducing the variety of steel joist sizes, the weight of steel used and cost of steel increased about 1.5 tons and $2,000 respectively. Although an increase in cost, this alternative open-web joist design could have significant time savings as the construction workers should learn how to put the similar joists up faster as the progress of the project moves along. Table 7 shows the weight and cost for each design. Calculations for steel framing for a more constructible design can be seen in Appendix O.

Table 7: Cost and Weights for Open-Web Bar Joists Designs

Total Cost of Framing Steel	(web joists similarized)	$1,029,866.49
Total Weight of structural Steel (lbs)	(web joists similarized)	413666.665
Total Cost of Framing Steel	(first web joist design)	$1,028,047.12
Total Weight of structural Steel (lbs)	(first web joist design)	410854.283

4.5 Schedule

Open-Web bar joists can be set at a faster rate than beams, because they are smaller and lighter than I-beams. I-beams can be set at an average rate of 45 beams or 20 tons a day (RS Means Construction Cost Data, 2012). Bar joists on the other hand can be set at a rate of 75-80 beams a day (RS Means Construction Cost Data, 2012). An image of the schedule can be seen in Figure 53, showing that an open-web bar joists design can be completed on July 11th. This schedule was built on the assumption that shop drawings would be approved in the same amount of time as for the original structural steel system, and it would take the same amount of time to procure the steel for open-web bar joists as W-shaped sections on site. Using joists will require more steel members than using just wide flange beams. The number of shipments could not be determined, because even though there are more members, the joists are lighter and could have more stacked on one flat bed. The equipment used for setting W-shaped sections could also be used for open-web bar joists, as the joists are lighter and would not require additional strength from cranes.



Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
	St Vincent Hospital St Vincer	137	137	0%	29-Feb-12	06-Sep-12	78
	St Vincent Hospital.03A Cc	137	137	0%	29-Feb-12	06-Sep-12	78
	St Vincent Hospital.05A Sti	91	91	0%	07-Mar-12	11-Jul-12	83
A1410	Prep/SBMT Shop Drawings	22	22	100%	07-Mar-12	05-Apr-12	106
A1420	R/A Submittals Metal Stairs	10	10	100%	03-Apr-12	16-Apr-12	71
A1430	RVW/APPRV Shop Drawin	5	5	100%	04-Apr-12	10-Apr-12	43
A1440	Prep/SBMT Shop Drawings	2	2	100%	06-Apr-12	09-Apr-12	91
A1450	RVW/APPRV Shop Drawin	10	10	100%	06-Apr-12	19-Apr-12	38
A1460	R/A Submittals Metal Stairs	10	10	100%	06-Apr-12	19-Apr-12	81
A1470	P/S Submittals Metal Railing	15	15	100%	06-Apr-12	26-Apr-12	83
A1480	FAB/Deliver Steel Framing [	40	40	100%	06-Apr-12	31-May-12	88
A1490	RVW/APPRV Shop Drawin	10	10	100%	09-Apr-12	20-Apr-12	106
A1500	Prep/SBMT Shop Drawings	1	1	100%	10-Apr-12	10-Apr-12	96
A1510	RVW/APPRV Shop Drawin	5	5	100%	10-Apr-12	16-Apr-12	91
A1520	RVW/APPRV Shop Drawin	1	1	100%	11-Apr-12	11-Apr-12	96
A1530	FAB/Deliver Steel Framing [	29	29	100%	13-Apr-12	23-May-12	38
A1540	FAB/Deliver Steel Framing [	40	40	100%	17-Apr-12	11-Jun-12	88
A1550	FAB/Deliver Steel Framing [	40	40	100%	18-Apr-12	12-Jun-12	88
A1560	FAB/Deliver Steel Framing	24	24	100%	20-Apr-12	23-May-12	53
A1570	FAB/Deliver Metal Stairs C	30	30	100%	20-Apr-12	31-May-12	71
A1580	FAB/Deliver Metal Stairs B	30	30	100%	20-Apr-12	31-May-12	81
A1590	FAB/Deliver STR Steel Den	23	23	100%	23-Apr-12	23-May-12	54
A1600	R/A Submittals Metal Railing	10	10	100%	27-Apr-12	10-May-12	83
A1610	FAB/Deliver Metal Railings	30	30	100%	11-May-12	21-Jun-12	83
A1660	Mezanine Steel Columns	13	13	100%	24-May-12	11-Jun-12	
A1750	Structural Steel Erection Be	0	0	100%	24-May-12		
A1710	Mezanine Framing	1	1	100%	11-Jun-12	11-Jun-12	
A1720	2nd and 3rd Floor Framing a	2	2	100%	11-Jun-12	13-Jun-12	
A1730	Other Steel Columns	2	2	100%	13-Jun-12	15-Jun-12	
A1650	Steel Detailing	19	19	100%	14-Jun-12	11-Jul-12	110
A1740	Other 2nd and 3rd Floor Fra	9	9	100%	15-Jun-12	27-Jun-12	
A1760	2nd and 3rd Floor Metal Dec	5	5	100%	22-Jun-12	29-Jun-12	
A1770	Roof Framing	6	6	100%	27-Jun-12	04-Jul-12	
A1780	Mezanine Metal Decking	3	3	100%	29-Jun-12	04-Jul-12	
A1790	Roof Metal Decking	6	6	100%	04-Jul-12	11-Jul-12	
A1620	Structural Erection Complete	0	0	100%		11-Jul-12	

Figure 55: Structural Steel Schedule for Open-Web Bar Joists

This schedule can be used for both alternative open-web bar joist designs, as both designs have the same amount of open-web bar joists and wide flange beams. The second design of using uniform joists would tend to make the design more constructible and improve the schedule, even more, due to lack of confusion and the learning curve. There would be less confusion on site as most of the joists would be the same, and the construction workers would not have to sort through a bundle of joists to find the proper ones for each bay. This would also improve the learning curve, as the workers would learn what was needed to construct each bay. By working with the same joist the workers would not have to guess at the best method for construction, but instead would gradually learn and improve on the process of using the joists as they worked on the whole building. A table of milestones for the project can be seen in Table 8.

Table 8: Milestone Dates of Open-Web Bar Joist Construction

Foundation Complete	17-May-12	All Shop Drawings Submitted	10-Apr-12
Concrete Deck Complete	16-Jul-12	All Shop Drawings Approved	11-Apr-12
Slab on Grade	6-Sep-12	Fabrication and Delivery	12-Jun-12
Concrete Complete	6-Sep-12	Steel Erection Begins	24-May-12
		Steel Erection Finished	11-Jul-12

5.0 Floor System with Precast Concrete Planks

Upon completion of investigating the open-web bar joist structure, a precast concrete plank floor system for the St. Vincent Cancer Center was designed and examined using similar methods. The precast concrete model was designed according to PCI standards. A *Revit* model was created using this design and then analyzed in *Robot*. Cost and schedule were also explored to explore any savings that the precast planks may offer.

5.1 Design of Floors

Precast concrete slabs have been increasing in popularity throughout the construction industry (PCI, 1998). These slabs can be used for almost any part of the project, from the floors, to the walls, to the roof. The design and construction of precast slabs have a great potential reduce the cost and time frame of a project.

For this alternative design, it was determined precast hollow-core slabs would be the best type of precast slab to use for multiple reasons. The top surface can be prepared for floor installation, while the underside can be used as a finished ceiling with very little alterations. If properly aligned, the voids in the hollow core slab can be used for electrical, mechanical, or plumbing runs. Structurally, a hollow core slab provides the efficiency of a prestressed member for load capacity, span range, and deflection control. Hollow core slabs also have excellent fire resistant ratings and sound transmission characteristics (PCI, 1998).

The design of a precast slab starts with the spanning direction, as they are one way spanning units (Ching, 2008). The spans of precast range from 12' to 40', and a rule of thumb for their depth is the span divided by 40. Site cast concrete topping that is reinforced with welded wire fabric or reinforcing bars at a 2-inch minimum can be applied to form a composite structural unit. The concrete topping ranges from 2 inches to 3½ inches in thickness. It forms a smooth top surface and conceals any irregularities, increases the capacity of the floor system, while providing additional fire-resistance. Concrete topping of the precast slab provide the structural behavior of a composite floor system, reference Section 2.5.4. Figure 56 below, shows how a precast slab is designed to provide composite behavior with an I-beam.

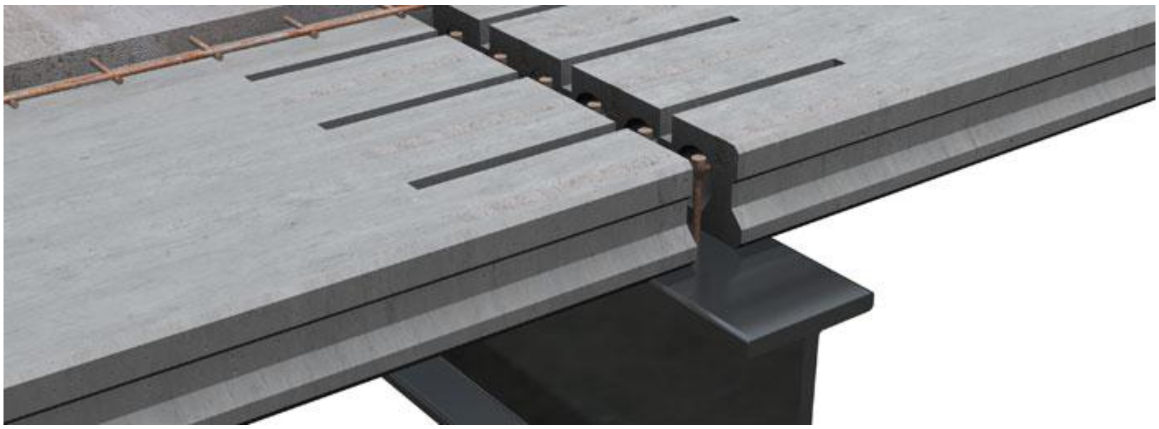


Figure 56: Composite Precast Slab

The hollow-core precast slabs spanning ability allows for a reduction in the floor systems quantity of structural steel. The St. Vincent baseline model was analyzed to remove any beams that are not necessary for support of the precast slabs. It can be seen in Figure 57 that the interior beams of the bays were removed. The girders of the bays were not removed as they maintain the structures rigid frame. The precast slabs for all floors will be orientated to span in the longer direction of the building, as seen in Figure 57, 58, and 59, represented by the double sided black arrows.

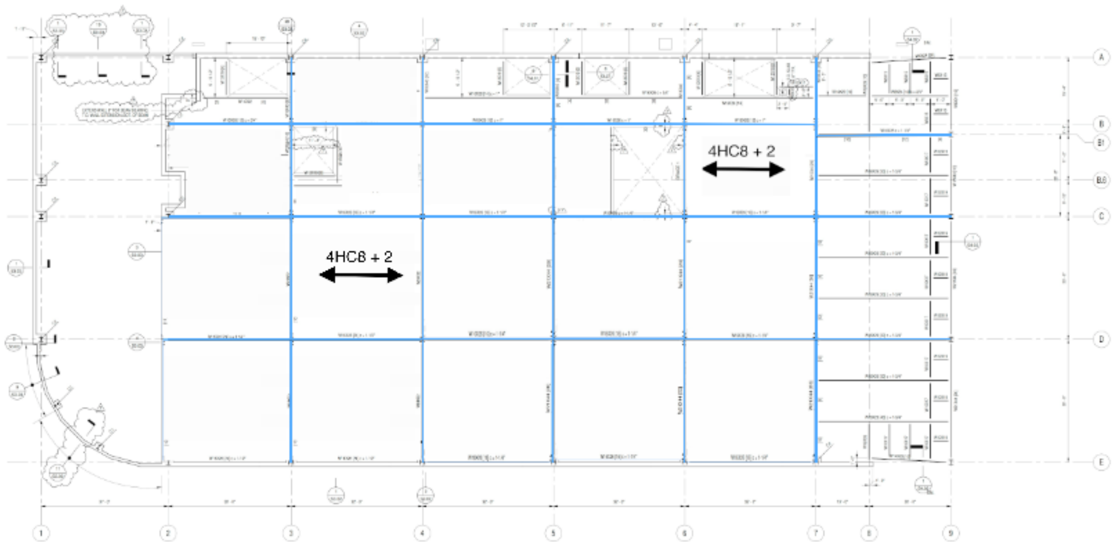


Figure 57: Beam Design for Precast Slabs Floor 2

It can be seen in the figures that some bays were not altered from the baseline design. The bays with irregular openings or design were not altered. In Figure 58 and 59 the rounded edge was not altered, as it must maintain its structural capacities. As seen in the figures, several edge bays of the structure were not altered because they have complicated interior beams that would require a redesigned floor system.

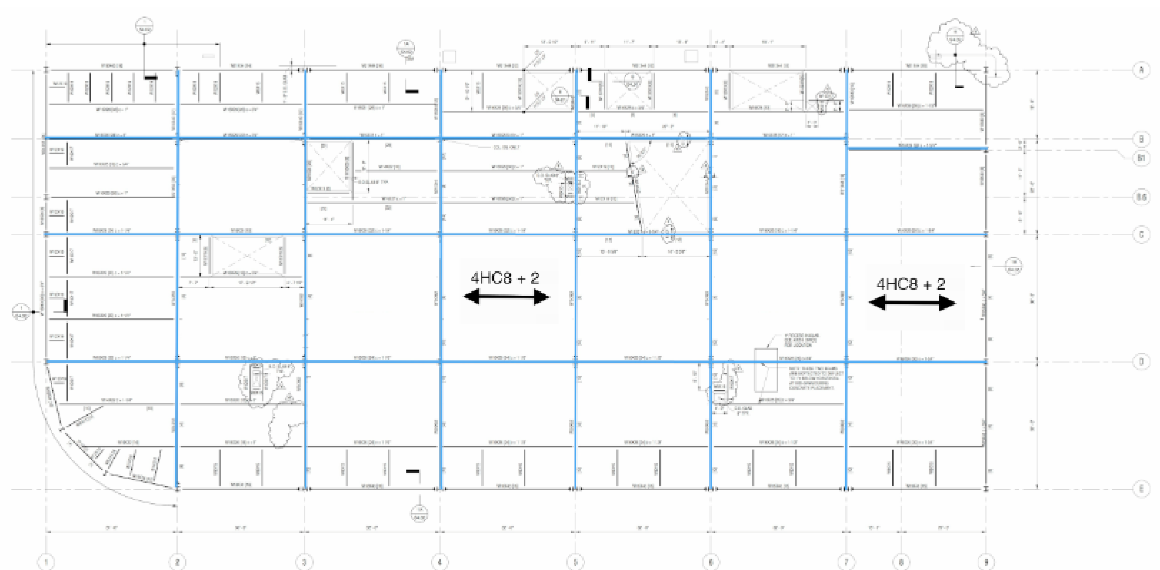


Figure 58: Beam Design for Precast Slabs Floor 3

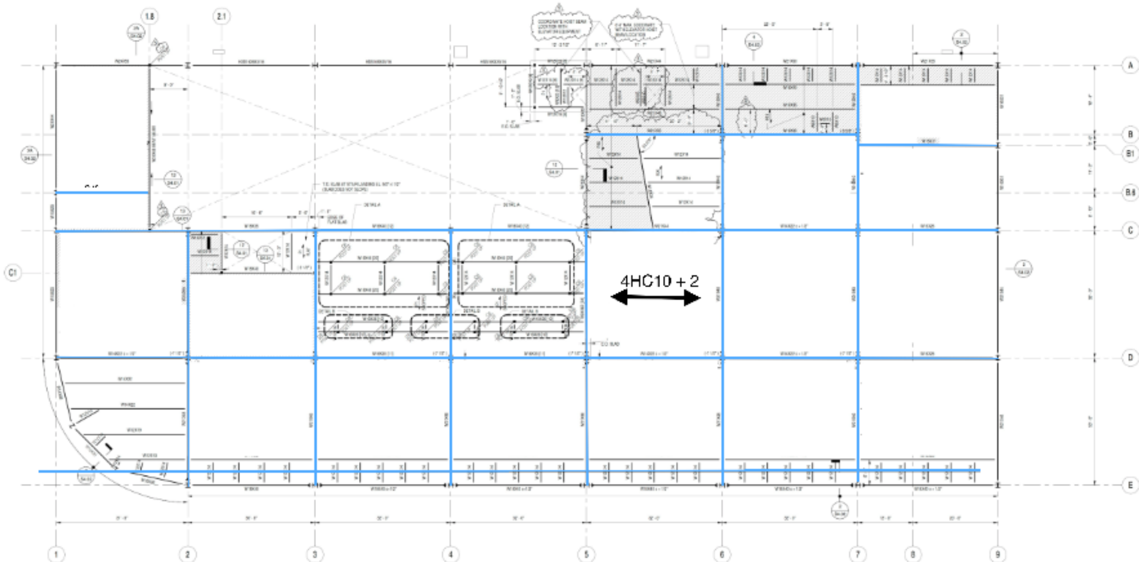


Figure 59: Beam Design for Precast Slabs Roof

The precast concrete on the roof of the St. Vincent has a higher potential for structural failure than the floor systems. This is because the structural steel in place for the baseline model was designed with the intent to support only the roof loads and the steel decking only. In the initial design only a small area of the roof will have steel decking and cast in place concrete. Also, the roof system shall support mechanical systems and therefore as seen in Figure 59, there is a more complicated beam design than the other floors. The live load on the roof is also the highest live load applied to the building. These reasons provide further complications for the precast concrete system; however, the design will be completed the same the floor systems.

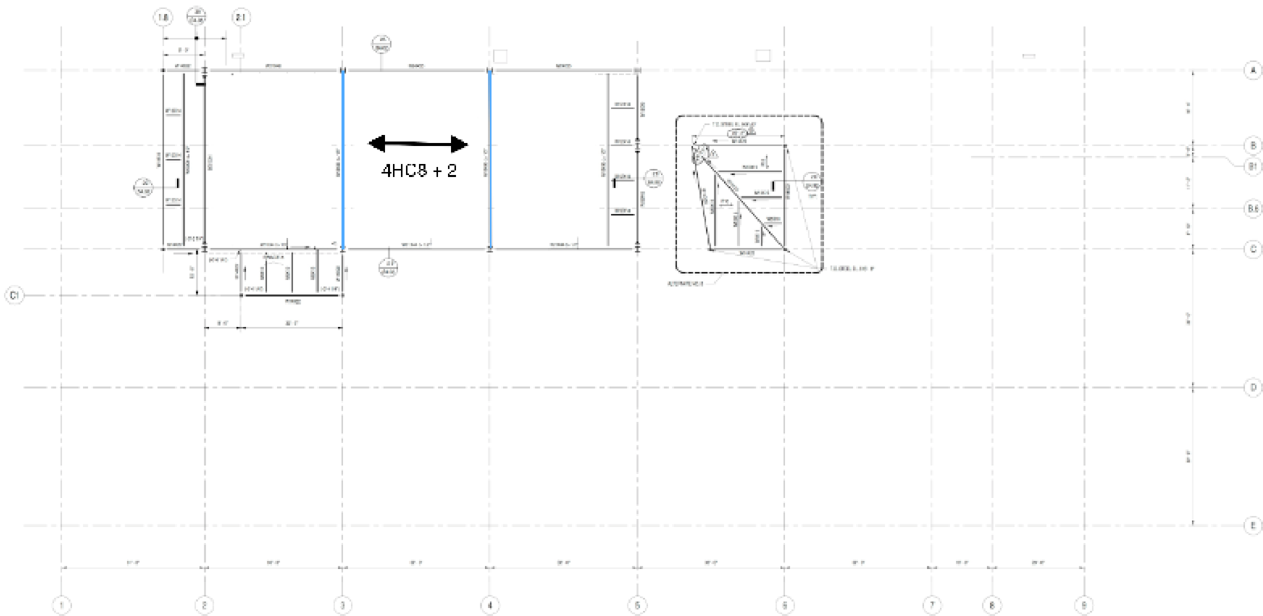


Figure 60: Beam Design for Precast Mechanical Roof

The precast design of the mechanical roof will be based off the beam system in Figure 60. The outer edges of the bays were not to be removed as they have a unique design. However, all other interior beams of the system were removed.

The next step in the design of the precast floor systems was to select the size of the hollow-core precast slab to be used on each story of the building. To do such, the Seventh Edition of the *PCI Design Handbook* was used. The handbook provides tables of safe superimposed live loads based on the span of the slab ("*PCI Design Handbook*"). Hollow core precast slabs are only listed for 4-foot widths. The thickness of the slab was chosen based on the span of the slab and the live load for each area specified in this report, Section 3.2. The *PCI Design Handbook* offers two tables for hollow-core, one for no topping and one for 2 inch normal weight concrete topping. The table with the topping was used to select the precast slab. The tables provide a dead load for the concrete with or without topping, and include a safe load of 15 lb/ft^2. This safe load is a tolerance for MEP material that may be run through the slab, or supported by the slab.

The thickness of the hollow-core precast concrete slab was determined for each floor. It was found that for all floors except the roof 4HC8 + 2 hollow-core concrete would be the smallest precast slab that meets the superimposed service load criteria (PCI 3.6 Hollow-Core Tables). This precast section is labeled as 4HC8 + 2; 4 for width in ft, HC for Hollow-Core, 8 for the depth of the slab, and + 2 representing the 2 inch normal weight concrete topping. The roof system has a live load of 127.75 psf with the longest span of 33 feet, and the precast section for this area was found to be 4HC10 + 2.

Precast concrete has strands of steel wires that are used in the prestressing process ("*PCI Design Handbook*"). To form the strand a few wires are spun together in a helical form in order to form a prestressing strand. (Sengupta and Menon). The strand designation provides the concrete slab with different strength capacities. For floors 2 and 3, the 4HC8 + 2 concrete section will have 78-S strands. This refers to 7 strands in the 4 foot width, 8/16 inch diameter of strands, and S stating that the strands are straight. The Roof will have 4HC10 + 2 concrete with a strand designation of 68-S. Finally, the mechanical roof 4HC8 + 2 concrete section will require a strand designation of 76-S; 6 meaning 6/16 inch strands. A summary of the precast concrete selections based on the design loads is provided in Appendix Q.

Typical lead times for precast hollow core slabs are about eight weeks. Four weeks of this time period consists of shop drawing design and approval. The other four weeks are production of the hollow core slab (Nesil Normile, personal communication, January 25, 2013). The units are cast in steam-cured in a plant off site, transported to the construction site and then set in place as rigid components with cranes (Ching, 2008). This production cannot be started until a receipt of the approved shop drawings is printed. Many times the size of the precast is limited by the means of transportation. It is also important to note that precast slabs may provide more difficulty for buildings with irregular shapes.

5.2 *Revit* Model

Similar to the design of the open-web bar joist model, design drawings were used to build the precast plank *Revit* model. As discussed in Section 5.1, the design called for the I-beams in various bays of the baseline model to be removed. Also, the curved corner was removed and a rectangular frame was used to avoid connection and structure errors in *Robot*. The hollow core planks were positioned laterally per the design drawings to act as lateral support in the structure. A *Revit* rendering of the precast hollow core planks on the structural steel is shown is Figure 61 below. A 2" thick cast-in-place concrete floor was added to each level of planks, eliminating the steel decking and reducing the total concrete poured. To finalize the *Revit* model, the building design loads were placed in accordance to previous models, with the only differing loads being the dead loads for the planks. Figure 62 displays the final precast plank *Revit* model and a view from *Revit* showing the design loads.

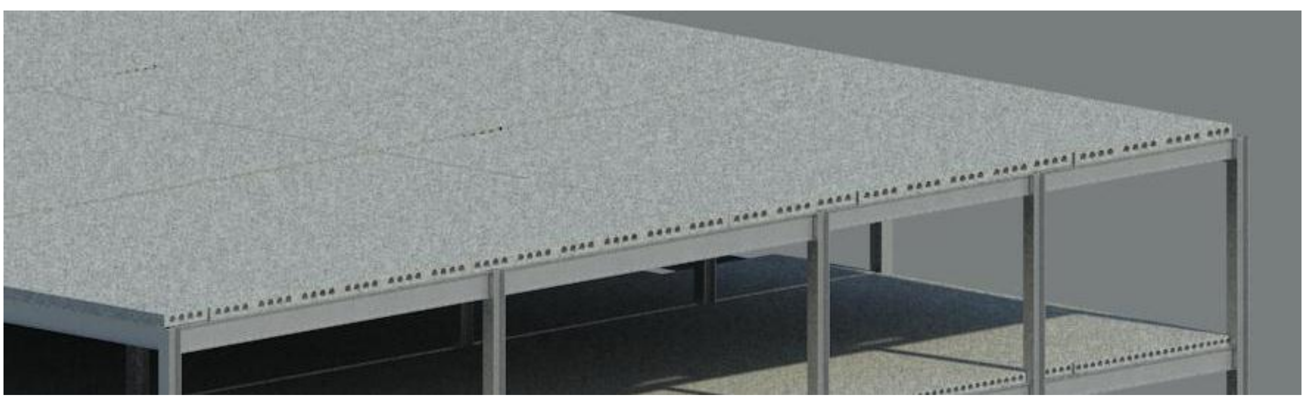


Figure 61: Precast plank *Revit* rendering

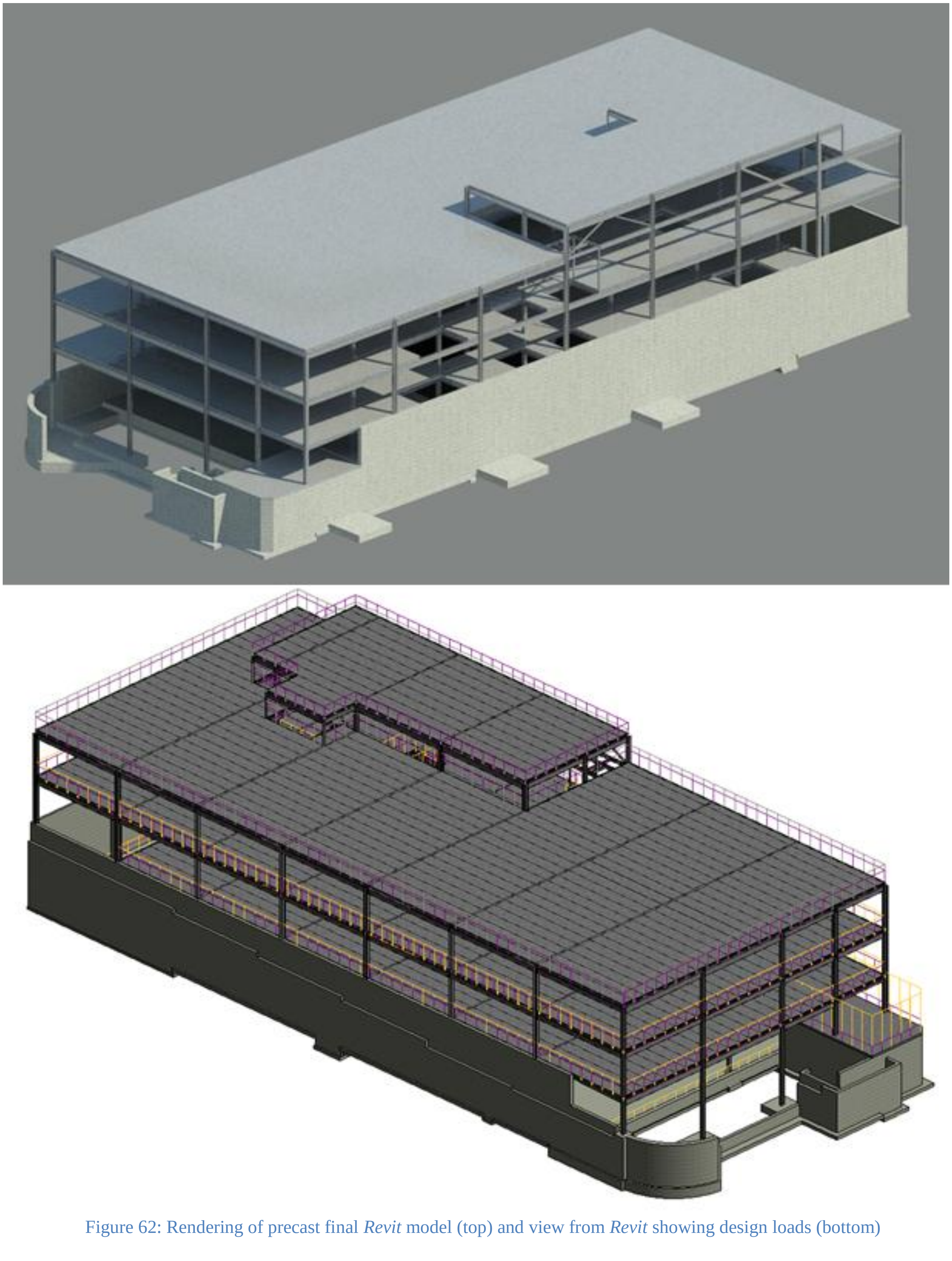


Figure 62: Rendering of precast final *Revit* model (top) and view from *Revit* showing design loads (bottom)

Figure 62 displays the design loads acting on the precast *Revit* model of St. Vincent Hospital. For the precast section the dead loads used were different than that of the prior alternative designs. Instead of the dead load of the baseline models cast-in-place concrete slab on steel decking this floor system consists of a dead load of the precast concrete. The dead loads of the precast slabs are provided in the *PCI Design Handbook*. The 8-inch slab with 2 inch topping on floors 2, 3, and the mechanical roof has a dead load of 81 psf. The roof has a 10-inch precast slab with a dead load of 93 psf. These loads were applied to the *Revit* model with the design loads and ASD factoring of the baseline model specified in Section 3.2.

5.3 *Robot* Analysis

As with the other *Revit* models, the precast model was analyzed using *Robot*. All of the same settings were used for exporting the model from *Revit* except for one. When attempting to export the model, the "execute model correction" feature caused numerous errors. The precast plank elements act as beams in the analytical model, depicted in Figure 63. The orange colored lines are any elements acting as beams for the structure. The left side shows a typical bay layout for the baseline model, while the right side shows the precast plank layout. While this is the correct structural usage for the planks, the analysis was identifying overlapping elements throughout the *Robot* model and was therefore unable to complete calculations. The error message that was displayed can be seen below in Figure 64, with the elements with errors highlighted in red.

Figure 63: Analytical model for typical level 2 bays (baseline vs. precast planks)

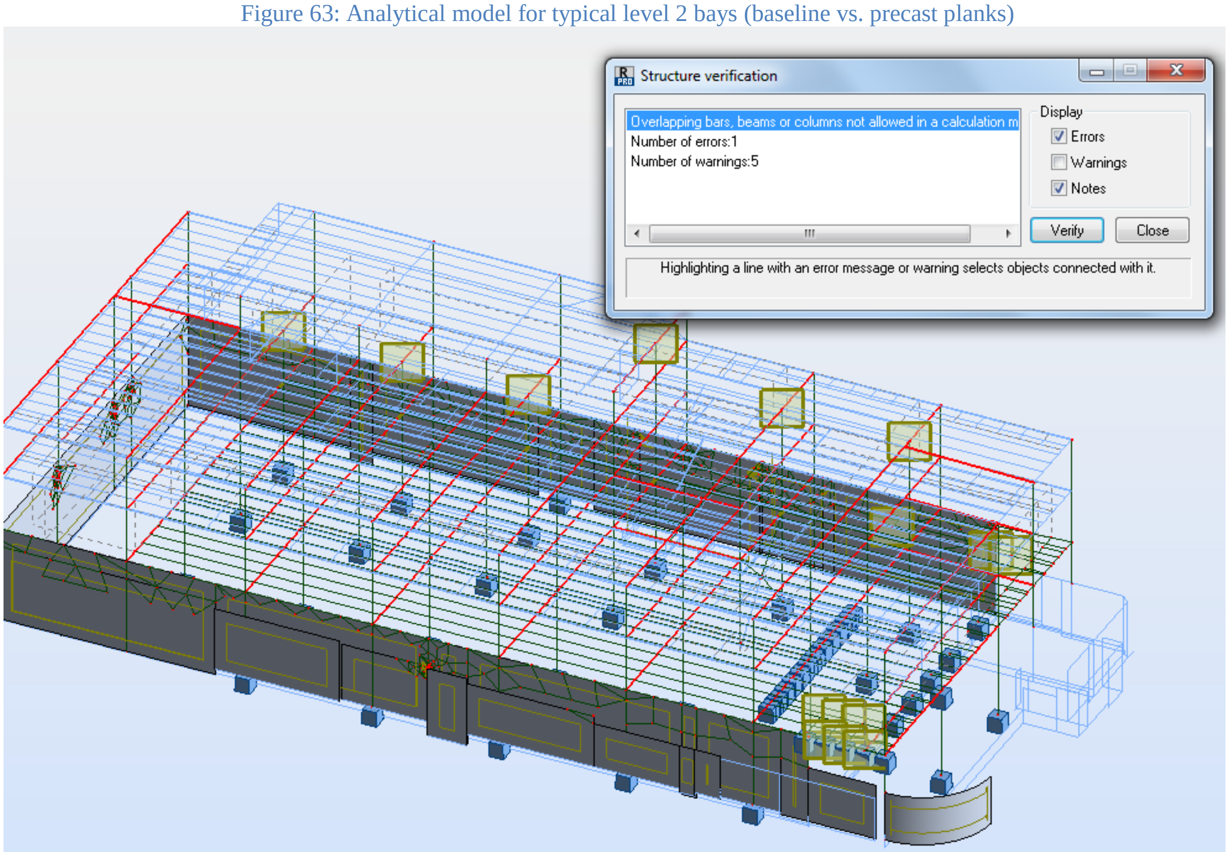


Figure 64: Error message in *Robot* for initial precast plank analysis

Once this problem was corrected, the precast plank model could be investigated with the same methods used in other analyses.

Following the calculations in *Robot*, the loads were factored and MYY maps were developed for each floor, shown below. In the following *Robot* model MYY maps it can be seen that once again the moment values are very small relative to the design loads provided. As verified in previous *Robot* analysis sections the software has interpretation issues with the load path that is producing errors. However, the maps still provide the team with data that can be used to evaluate the alternative design.

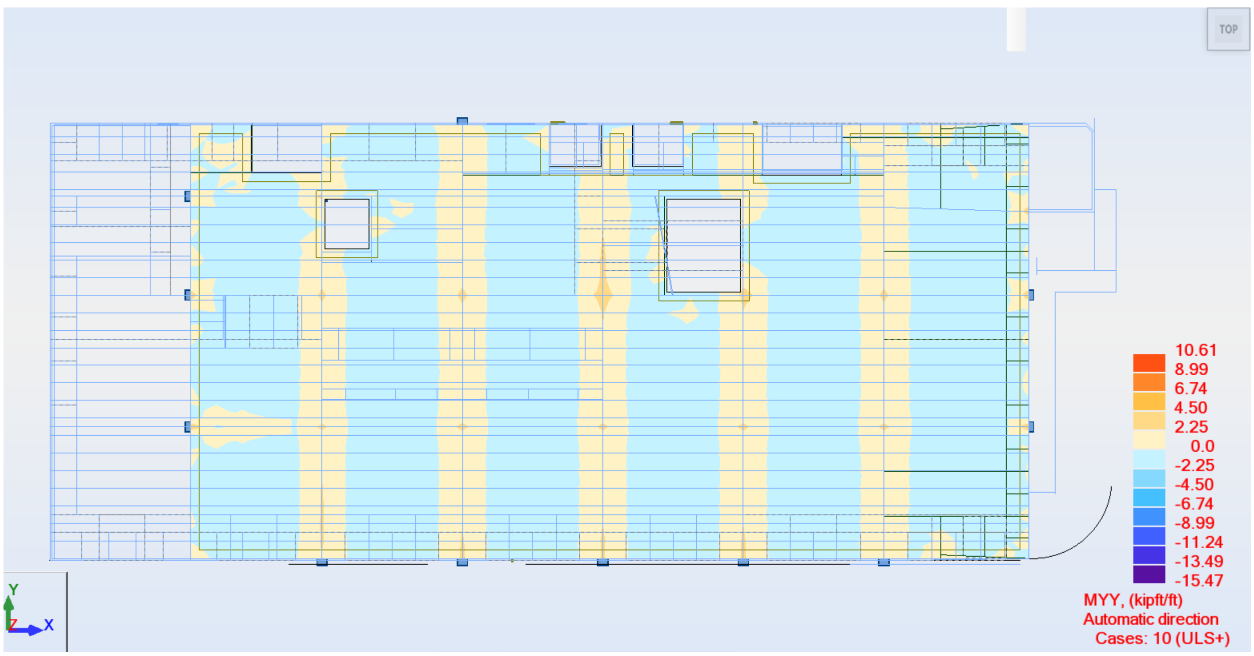


Figure 65: Precast Plank Level 2 MYY Map

Figure 65 displays the *Robot* model MYY maps for the second floor. The moment is distributed so that at any point along the y-axis the moment values are rather similar given any point along the x-axis. In the center of the concrete spans the moment has the greatest negative YY value. The moment value is rather close in a positive value at the beginning and end of each span of the precast sections. The load path doesn't seem to be traveling through any specific columns and is evenly distributed throughout the frame.

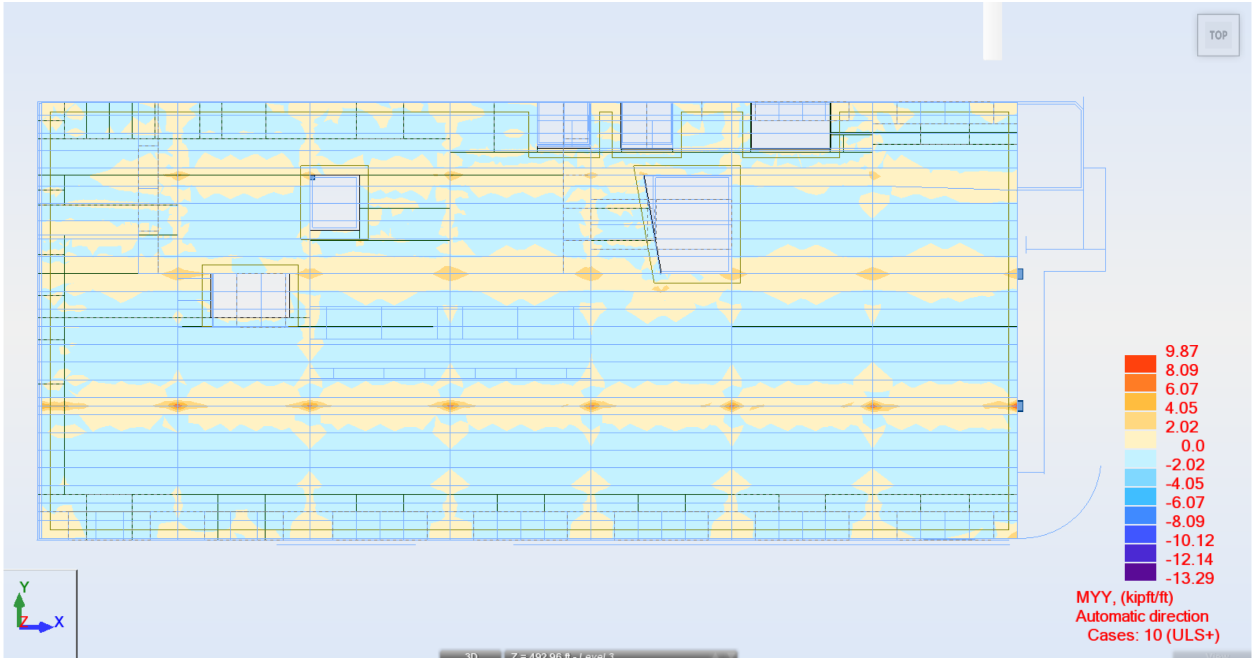


Figure 66: Precast Plank Level 3 MYY Map

Figure 66 displays the MYY map of the *Robot* analysis for the designed precast on the 3rd floor of St. Vincent's Hospital. It can be seen that the moment distribution is very different than that of floor 2. Instead of the moment being uniform in the y-axis, this figure shows that the moments are fairly uniform in the x-axis. This means that the value at a given point along the y-axis would produce similar values of the moment along the x-axis. The columns on this floor have a high moment, which may mean the *Robot* software is interpreting the load path incorrectly.

Figure 67 represents the moment distribution on the roof. This area was of concern, as the high live load required a thicker and heavier precast slab. Like in floor 3, the moment is distributed evenly along the column lines in the x-axis. The column lines in the y-axis don't seem to have much effect on the moment distribution. The columns don't seem to have concentrated moments on them like in floor 3.

The *Robot* analysis of the mechanical roof system is shown in Figure 68. The moments are much smaller than that of the other floors, which *Robot* automatically adjusts the color scale to. This magnifies the problem areas; however the beam with the red moment only has a moment of about 4.69 kip-ft. The moment distribution is similar to the second floor, as the column lines in the y-axis provide similar values of moment.

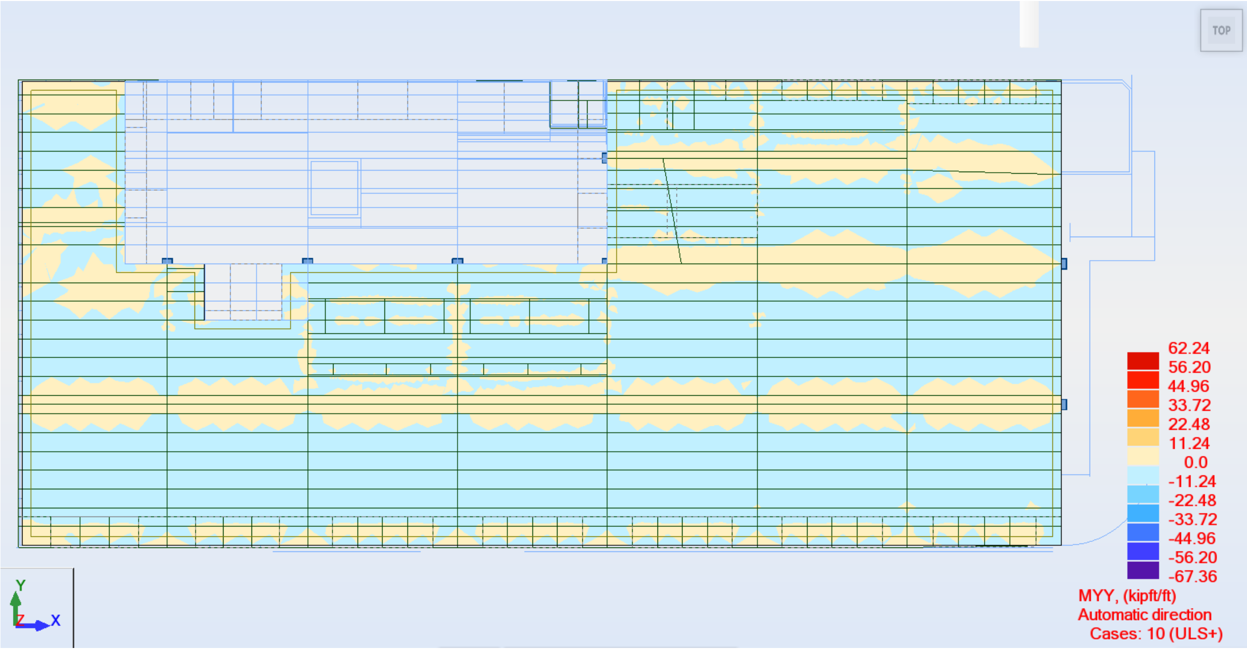


Figure 67: Precast Plank Roof MYY Map

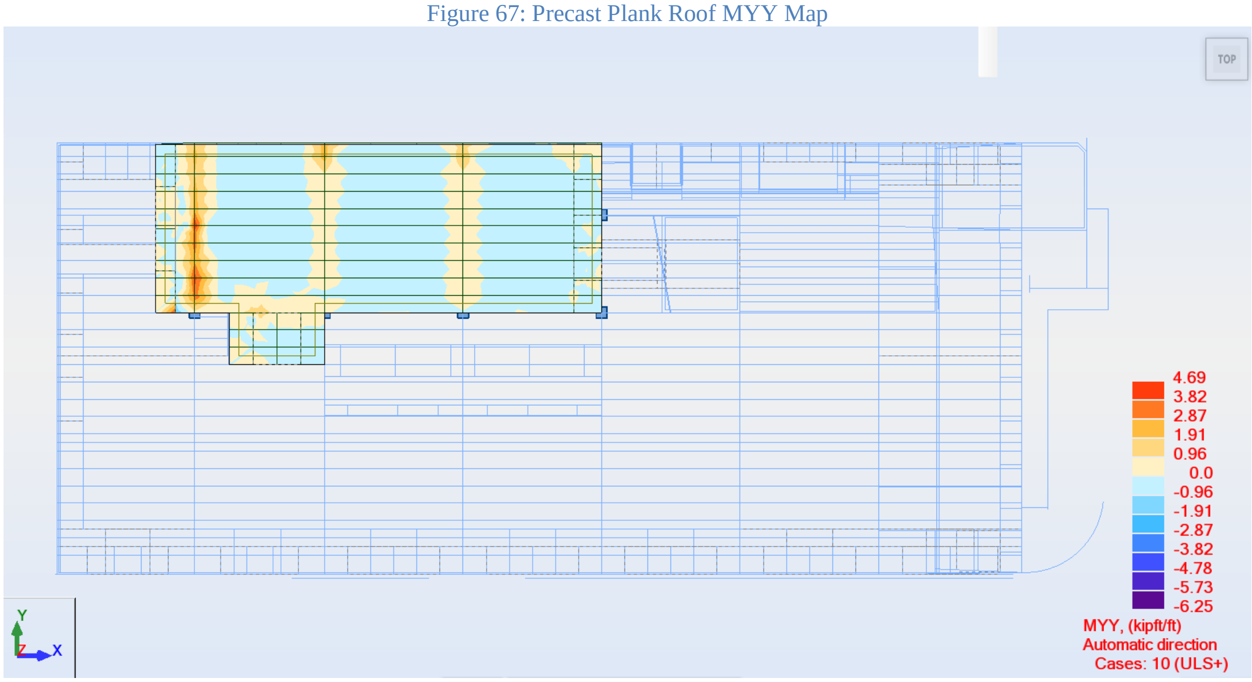


Figure 68: Precast Plank Mech Roof MYY Map

5.4 Cost

Once a *Revit* model with hollow core precast slabs was created, an RS Means cost estimate was prepared. This figure was put together by replacing all slabs with hollow core precast slabs with a 2 in. concrete slab cover. Each bay was also re-designed because the precast slabs added structural support to the system. Due to this W-shaped sections could be reduced to just the girders in most bays, but maintained the W-shaped sections in irregular bay such as near elevators, staircases, and the rounded curve of the building. Table 9 below shows cost estimations for structural steel, and Table 10 shows the cost estimations for concrete using unit cost data from RS Means. The RS Means estimates include all necessary structural bolts and delivery to the job site for the structural steel as well as the welding and grouting to install the precast planks, (RS Means Construction Cost Data, 2012). A comprehensive breakdown of cost per member of the steel framing and precast hollow core planks can be seen in Appendix R.

Table 9: Cost estimations for Structural Steel in Precast Design

Steel Column Cost	$268,370.84
Steel Framing Cost	$875,880.78
Total Cost of Metal	$1,144,251.62
Cost per Ton	$4,899.67

Table 10: Cost Estimations for Concrete in Precast Design

Foundation Wall (CY)	$912,114.00
Footing (CY)	$221,888.24
Pilaster (CY)	$106,336.25
Hollow Core Concrete slab	$751,423.82
Total Cost of Concrete	$1,991,762.31

Another factor that must be considered is drilling holes through the precast planks for plumbing and HVAC systems. This important factor must be calculated in order to determine the true costs of the precast plank design. A true calculation could not be completed as a total number of holes and the sizes of these holes were not known. The cost for each size hole in precast planks can be seen in Table 11.

Table 11: Cost for Drilling Holes in Precast Planks (RS Means Construction Cost Data, 2012)

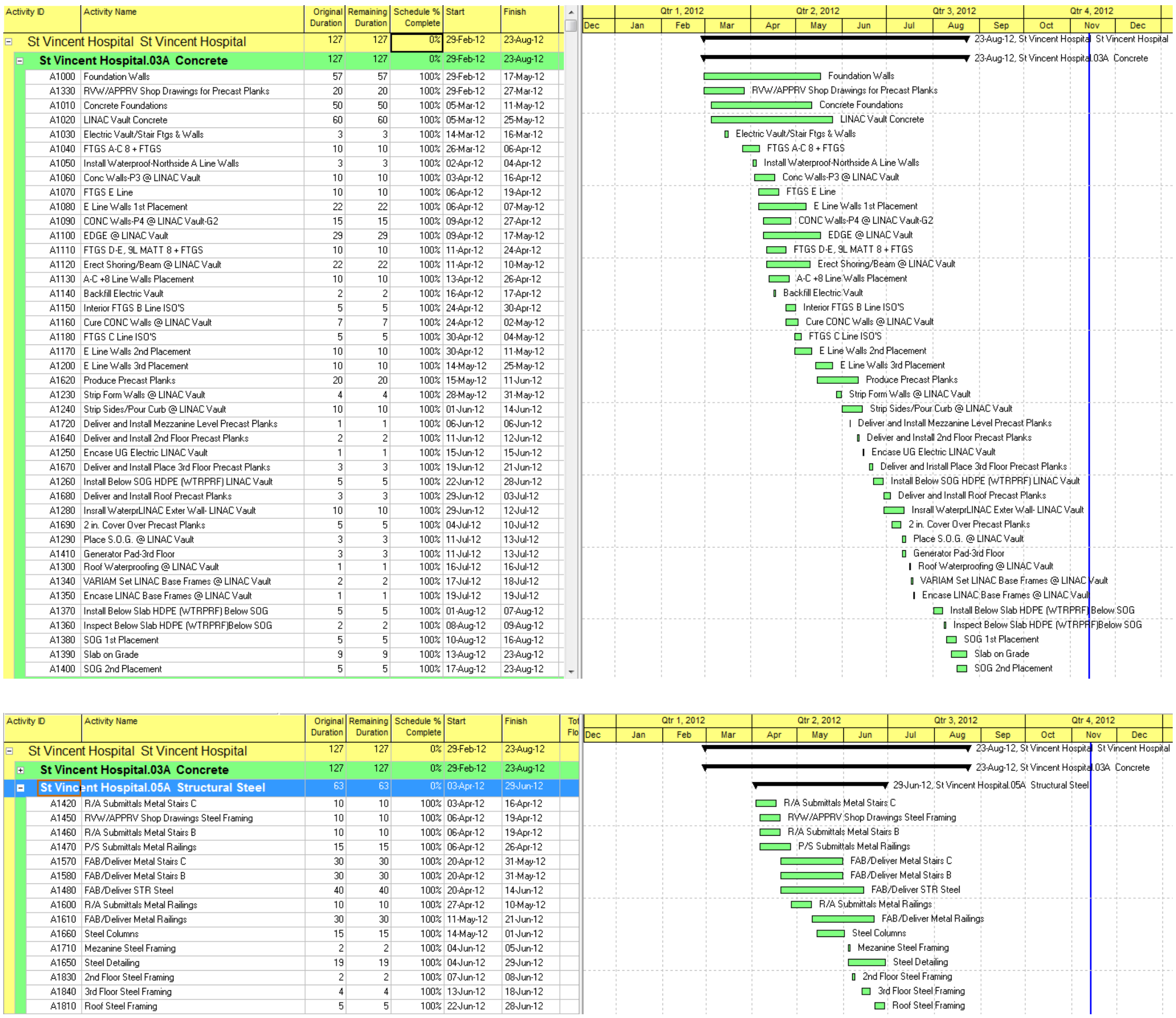
Diameter of Hole	Cost to Drill Hole	Cost for Additional 1" Depth
1"	$64.50	$0.81
3"	$69.50	$1.51
4"	$73.50	$2.24
6"	$79.50	$2.71
8"	$85.50	$3.62
10"	$95.00	$3.99
12"	$100.00	$5.65

5.5 Schedule

Precast Planks alter not only the concrete schedule, but also the steel schedule for a project. Due to the reduction of beams, not having to pour each floor of concrete, and having to drop off of materials well organized, a building with precast planks can be constructed faster. It takes approximately four weeks to approve shop drawings and four weeks to produce the planks after the receipt of the approved drawings depending on how busy the fabricator is (Nesil Normile, personal communication, January 25, 2013). An image of the schedule can be seen in Figure 67, showing that the concrete can be completed by August 23rd and structural steel work can be completed by June 29th. In order to complete these schedules on time, delivery of the planks becomes one of the most crucial parts of the project, as without these being delivered on the appropriate day the project would slow down. These drop-offs must be coordinated properly as there is limited storage space on site. The equipment Gilbane has on site to set W-shaped sections would be appropriate for setting the precast planks. A table of milestones for the project can be seen in Table 12. This schedule does not show any time devoted to drilling the necessary holes in the precast planks for the plumbing and HVAC systems. The value of time lost to planning and drilling holes for these systems and the number of holes needed was not known and could not be calculated.

Table 12: Milestones of Precast Plank Construction

Foundation Complete	17-May-12	Shop Drawings Approved for Structural Steel	19-Apr-12
Precast Shop Drawings Approve	27-Mar-12		
All Concrete Planks Placed	3-Jul-12	Fabrication and Delivery	14-Jun-12
Slab on Grade	23-Aug-12	Steel Erection Begins	14-May-12
Concrete Complete	23-Aug-12	Steel Erection Finished	28-Jun-12



Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish
	St Vincent Hospital St Vincent Hospital	127	127	0%	29-Feb-12	23-Aug-12
	St Vincent Hospital.03A Concrete	127	127	0%	29-Feb-12	23-Aug-12
A1000	Foundation Walls	57	57	100%	29-Feb-12	17-May-12
A1330	RVW/APPRV Shop Drawings for Precast Planks	20	20	100%	29-Feb-12	27-Mar-12
A1010	Concrete Foundations	50	50	100%	05-Mar-12	11-May-12
A1020	LINAC Vault Concrete	60	60	100%	05-Mar-12	25-May-12
A1030	Electric Vault/Stair Ftgs & Walls	3	3	100%	14-Mar-12	16-Mar-12
A1040	FTGS A-C 8 + FTGS	10	10	100%	26-Mar-12	06-Apr-12
A1050	Install Waterproof-Northside A Line Walls	3	3	100%	02-Apr-12	04-Apr-12
A1060	Conc Walls-P3 @ LINAC Vault	10	10	100%	03-Apr-12	16-Apr-12
A1070	FTGS E Line	10	10	100%	06-Apr-12	19-Apr-12
A1080	E Line Walls 1st Placement	22	22	100%	06-Apr-12	07-May-12
A1090	CONC Walls-P4 @ LINAC Vault-G2	15	15	100%	09-Apr-12	27-Apr-12
A1100	EDGE @ LINAC Vault	29	29	100%	09-Apr-12	17-May-12
A1110	FTGS D-E, 9L MATT 8 + FTGS	10	10	100%	11-Apr-12	24-Apr-12
A1120	Erect Shoring/Beam @ LINAC Vault	22	22	100%	11-Apr-12	10-May-12
A1130	A-C +8 Line Walls Placement	10	10	100%	13-Apr-12	26-Apr-12
A1140	Backfill Electric Vault	2	2	100%	16-Apr-12	17-Apr-12
A1150	Interior FTGS B Line ISO'S	5	5	100%	24-Apr-12	30-Apr-12
A1160	Cure CONC Walls @ LINAC Vault	7	7	100%	24-Apr-12	02-May-12
A1180	FTGS C Line ISO'S	5	5	100%	30-Apr-12	04-May-12
A1170	E Line Walls 2nd Placement	10	10	100%	30-Apr-12	11-May-12
A1200	E Line Walls 3rd Placement	10	10	100%	14-May-12	25-May-12
A1620	Produce Precast Planks	20	20	100%	15-May-12	11-Jun-12
A1230	Strip Form Walls @ LINAC Vault	4	4	100%	28-May-12	31-May-12
A1240	Strip Sides/Pour Curb @ LINAC Vault	10	10	100%	01-Jun-12	14-Jun-12
A1720	Deliver and Install Mezzanine Level Precast Planks	1	1	100%	06-Jun-12	06-Jun-12
A1640	Deliver and Install 2nd Floor Precast Planks	2	2	100%	11-Jun-12	12-Jun-12
A1250	Encase UG Electric LINAC Vault	1	1	100%	15-Jun-12	15-Jun-12
A1670	Deliver and Install Place 3rd Floor Precast Planks	3	3	100%	19-Jun-12	21-Jun-12
A1260	Install Below SOG HDPE (WTRPRF) LINAC Vault	5	5	100%	22-Jun-12	28-Jun-12
A1680	Deliver and Install Roof Precast Planks	3	3	100%	29-Jun-12	03-Jul-12
A1280	Insrall WaterprLINAC Exter Wall- LINAC Vault	10	10	100%	29-Jun-12	12-Jul-12
A1690	2 in. Cover Over Precast Planks	5	5	100%	04-Jul-12	10-Jul-12
A1290	Place S.O.G. @ LINAC Vault	3	3	100%	11-Jul-12	13-Jul-12
A1410	Generator Pad-3rd Floor	3	3	100%	11-Jul-12	13-Jul-12
A1300	Roof Waterproofing @ LINAC Vault	1	1	100%	16-Jul-12	16-Jul-12
A1340	VARIAM Set LINAC Base Frames @ LINAC Vault	2	2	100%	17-Jul-12	18-Jul-12
A1350	Encase LINAC Base Frames @ LINAC Vault	1	1	100%	19-Jul-12	19-Jul-12
A1370	Install Below Slab HDPE (WTRPRF) Below SOG	5	5	100%	01-Aug-12	07-Aug-12
A1360	Inspect Below Slab HDPE (WTRPRF)Below SOG	2	2	100%	08-Aug-12	09-Aug-12
A1380	SOG 1st Placement	5	5	100%	10-Aug-12	16-Aug-12
A1390	Slab on Grade	9	9	100%	13-Aug-12	23-Aug-12
A1400	SOG 2nd Placement	5	5	100%	17-Aug-12	23-Aug-12

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Tot Flo
	St Vincent Hospital St Vincent Hospital	127	127	0%	29-Feb-12	23-Aug-12	
	St Vincent Hospital.03A Concrete	127	127	0%	29-Feb-12	23-Aug-12	
	St Vincent Hospital.05A Structural Steel	63	63	0%	03-Apr-12	29-Jun-12	
A1420	R/A Submittals Metal Stairs C	10	10	100%	03-Apr-12	16-Apr-12	
A1450	RVW/APPRV Shop Drawings Steel Framing	10	10	100%	06-Apr-12	19-Apr-12	
A1460	R/A Submittals Metal Stairs B	10	10	100%	06-Apr-12	19-Apr-12	
A1470	P/S Submittals Metal Railings	15	15	100%	06-Apr-12	26-Apr-12	
A1570	FAB/Deliver Metal Stairs C	30	30	100%	20-Apr-12	31-May-12	
A1580	FAB/Deliver Metal Stairs B	30	30	100%	20-Apr-12	31-May-12	
A1480	FAB/Deliver STR Steel	40	40	100%	20-Apr-12	14-Jun-12	
A1600	R/A Submittals Metal Railings	10	10	100%	27-Apr-12	10-May-12	
A1610	FAB/Deliver Metal Railings	30	30	100%	11-May-12	21-Jun-12	
A1660	Steel Columns	15	15	100%	14-May-12	01-Jun-12	
A1710	Mezanine Steel Framing	2	2	100%	04-Jun-12	05-Jun-12	
A1650	Steel Detailing	19	19	100%	04-Jun-12	29-Jun-12	
A1830	2nd Floor Steel Framing	2	2	100%	07-Jun-12	08-Jun-12	
A1840	3rd Floor Steel Framing	4	4	100%	13-Jun-12	18-Jun-12	
A1810	Roof Steel Framing	5	5	100%	22-Jun-12	28-Jun-12	

Figure 69: Precast Plank Schedule for Concrete and Superstructure

6.0 Evaluation of Alternatives

Using the *Robot* MYY maps, the cost estimates, and the created schedules an evaluation of the alternative floor systems were completed. These comparisons provided results of the moment distribution throughout the structure for the baseline model, the open-web bar joist model, and the precast floor system. The costs were compared using the total cost difference from the baseline model to determine which system yields the greatest savings. Schedules were compared to determine which design could offer a potential saving of time, thus reducing cost for the project. A comparison of constructability was then completed to determine which design was the most feasible for construction.

6.1 Robot Results Evaluation

The *Robot* results provided the team with a means of evaluating the designs structural properties. The MYY maps provide information on areas to be concerned as they are overloaded. This is likely to happen in the design, as the original baseline model was altered to accommodate open-web bar joists and precast concrete. In a complete design of the systems, the savings and benefits of the alternatives would be magnified, as the building would be completely redesigned. For this evaluation the baseline model was compared to the alternative to determine the benefits offered by the simple redesign of the floor systems.

The first evaluation was made in an attempt to understand the load path interpretation of *Robot* software. In order to do so the systems foundation was altered to see if the load distribution was affected by the interpretation of the foundations rounded edge. Figure 70 shows the MYY maps of both designs. It can be seen that by changing the foundation, the moment distribution throughout the floor was altered. The square foundation proves to create a greater concentration of moment at the columns. Although these maps are not on the same scale it can clearly be seen that *Robot* software was interpreting the rounded edge differently than with the square foundation.   This proves that small changes to the design can have major effects on the system.

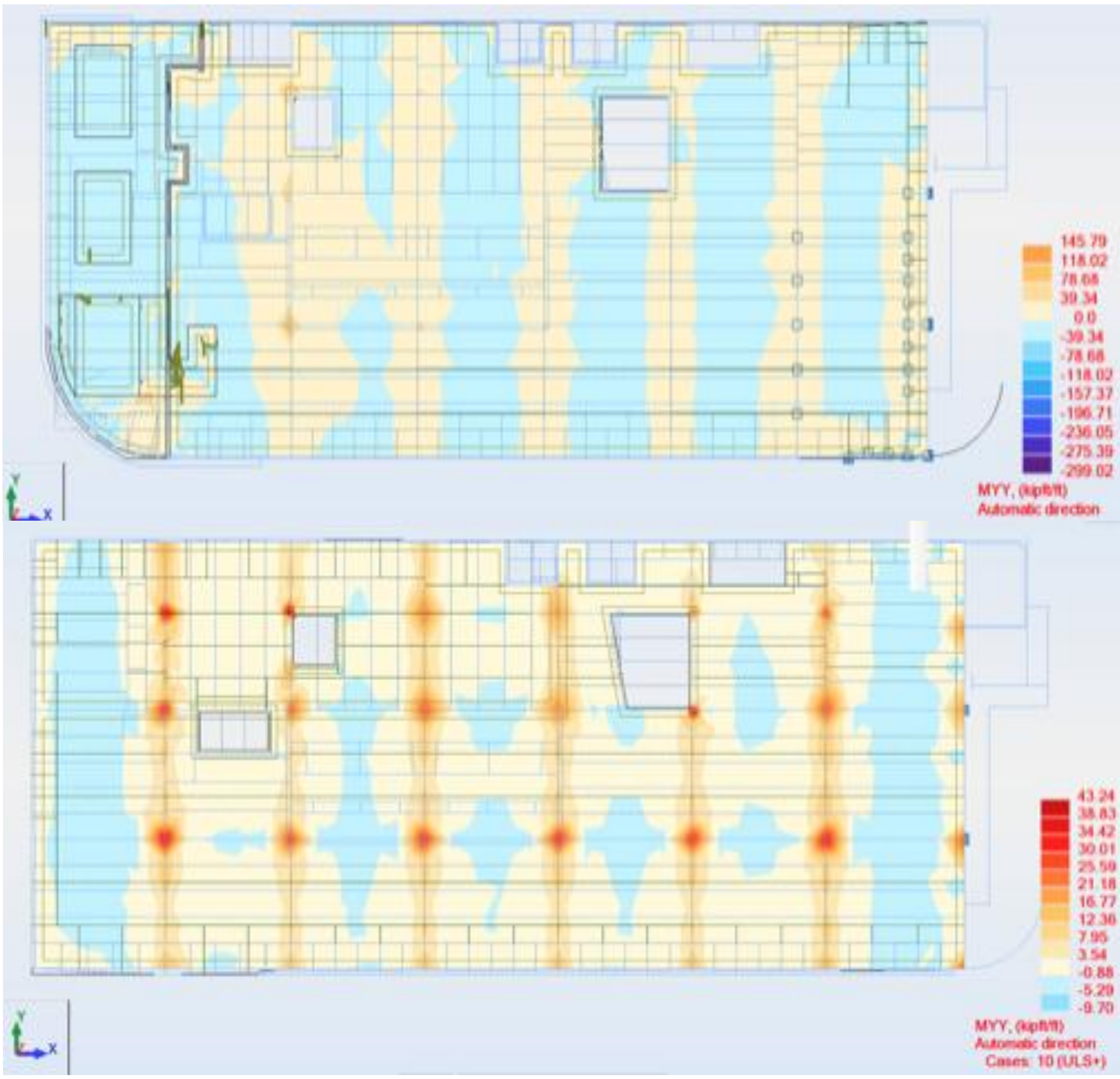


Figure 70: Floor 2 Square Vs. Rounded Edge

In section 3.3, the team determined not to use the magnitude of the moment diagrams, but the distribution in order to make an evaluation. In Figure 71, the comparison of *Robot's* MYY analysis of Floor 3 between the baseline and the open-web bar joist model are very similar. The moment distribution is vertical along the y-axis column line. It should be noted that for both designs the same loads and type of floor are used for the *Robot* analysis. The diagrams are on different scales, as the baseline model has a maximum of 140 kip-ft moments and the open-web bar joist only has a maximum moment of 30 kip-ft. The moment distribution patterns on the floors are very similar, which proves that *Robot* was either interpreting the load path incorrectly, or the structural design of the system called for a high moment at the columns.

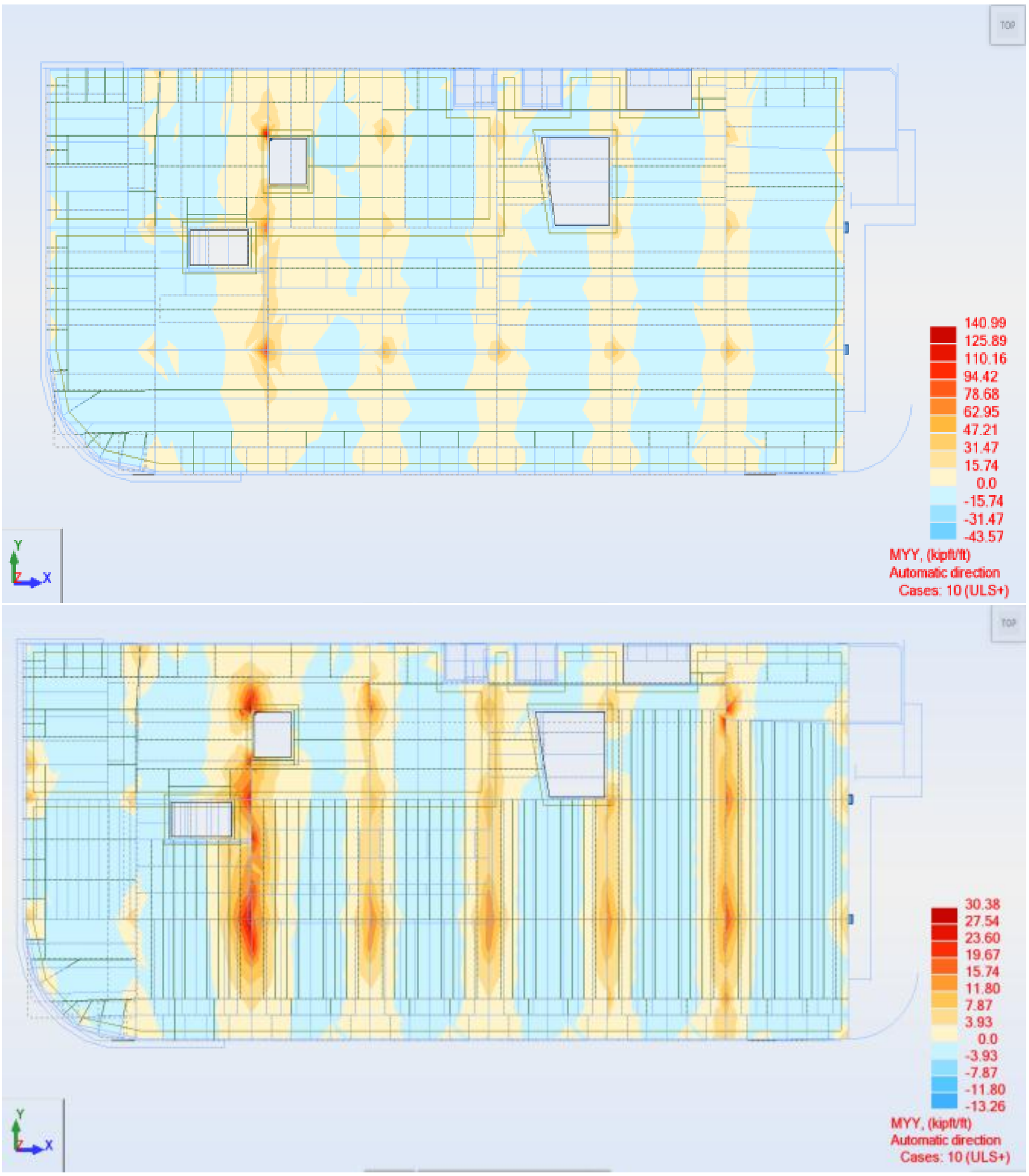


Figure 71: Floor 3 Baseline (top) vs. Open-Web Model (bottom)

The scale for the open-web bar joist compared to the baseline model was much smaller. This means that the maximum and minimum moments of the system are much smaller. The moment should be similar in magnitude as the same loads are applied. The open-web joists may be able to distribute the moment more evenly, as they are spaced much closer, but eventually the same floor loads need to be transferred to the girders supporting the loads and floor system.

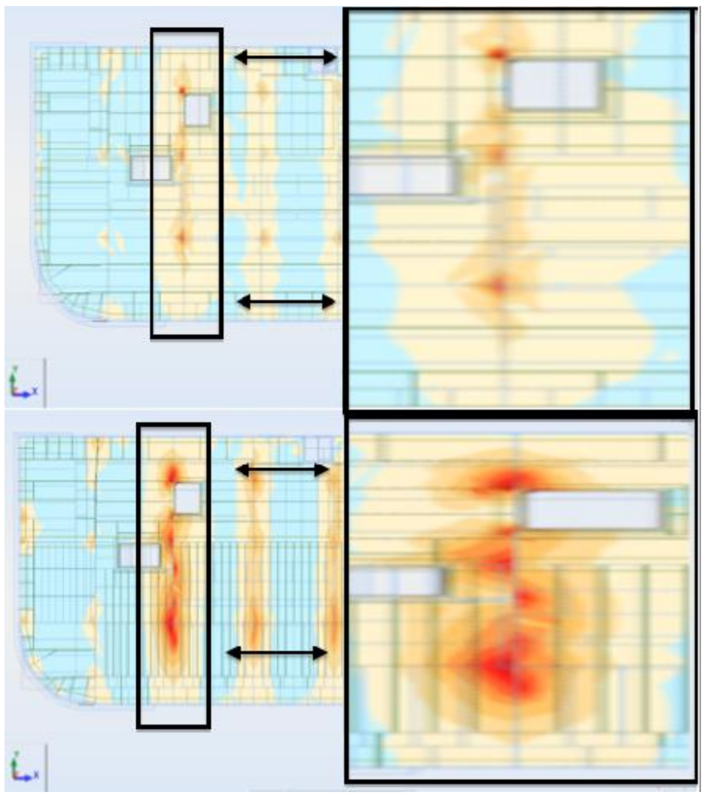


Figure 72: Column Line Moment Concentration

In Figure 72 above it can be seen that the same column line for the baseline and open-web bar joist has a high concentration of moment. This may be one of the reasons why the *Robot* software is providing inaccurate calculations.

Comparisons between the baseline model and the precast model, as shown below in Figure 73, show that the moment distribution is very different. In the baseline model, the moment is distributed evenly along the y-axis column line. In the precast model, the moment is distributed evenly along the x-axis on the girder line. This may be due to the removal of the internal beams in the precast model that were used to support the slab on deck in the baseline model. The precast slabs are designed to support themselves and the live load over a given span. They have much greater load capacities than the cast-in-place concrete floor system of the baseline model. Also, it can be seen that the moment is not as heavily concentrated in the columns for the precast slab system.

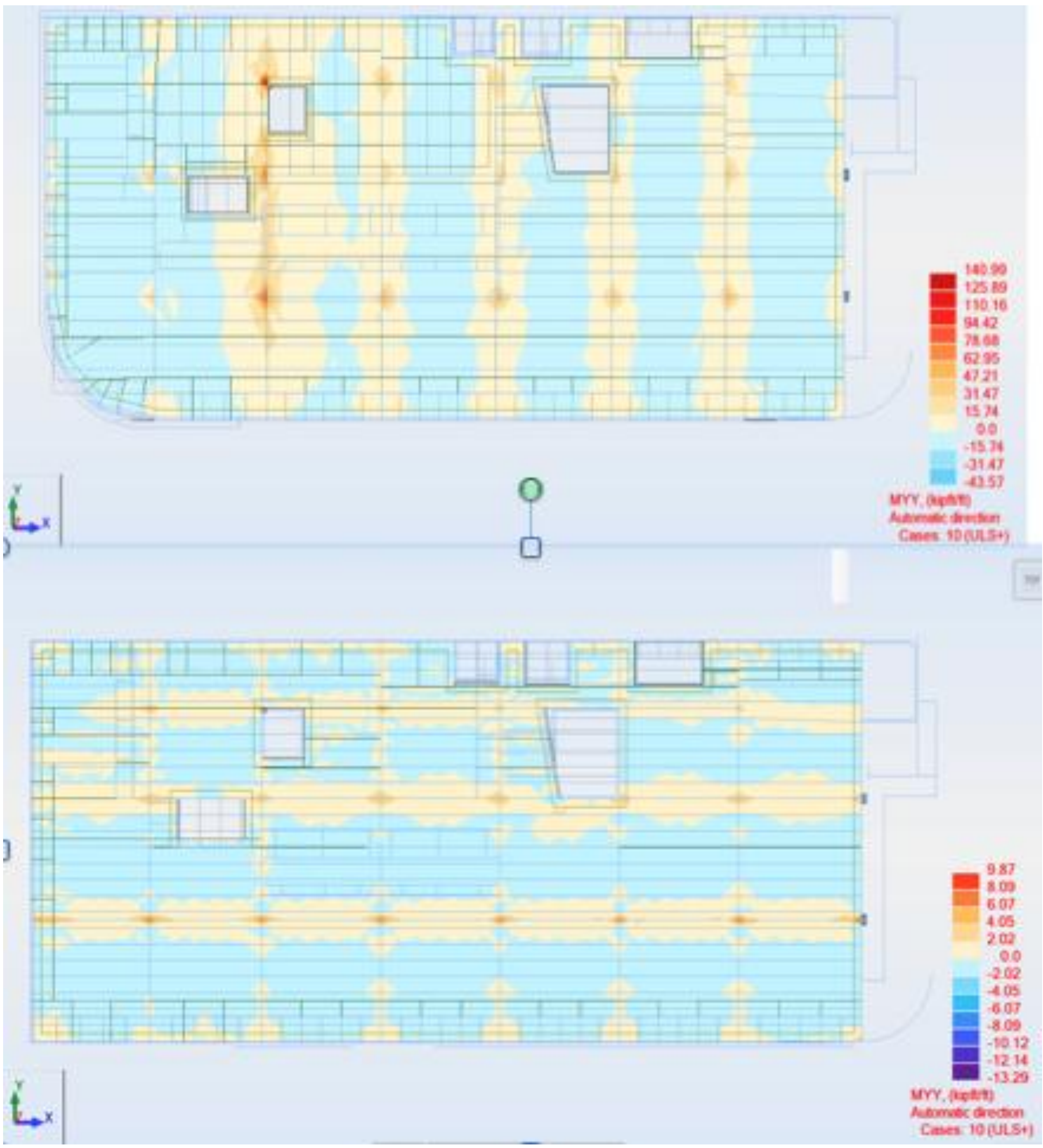


Figure 73: MYY Floor 3, Baseline (top), Precast (bottom)

Figure 73 (above) provides a much different scale for the moments on the floor systems. The precast system has a very small scale for the magnitude of the moment. This shows that *Robot* software interpreted the slab as many beams that carried the load. The load then however, was not distributed correctly to the girders and supporting frame, as the moment is too small for this. This implies that *Robot* treats the slab as have load carrying capacities. It is unclear how the *Robot* software interpreted the load path.

Figure 74 below displays the moment distribution on the second floor for all designs. It can be seen that the moment distribution on this floor is very similar between the baseline model and the two alternative models. This evaluation shows that the load path was not that much different for each model. However, on floor 3, the roof, and the mechanical roof the results vary greatly for each alternative design. The foundation of the building may have a significant impact on the second floor, and the way in which *Robot* interprets the load path through the columns may be magnified on the higher floors. It is also noticeable that the columns aren't carrying any loads. When comparing both alternatives to the baseline model the load path is not affected despite the structural differences in the alternatives.

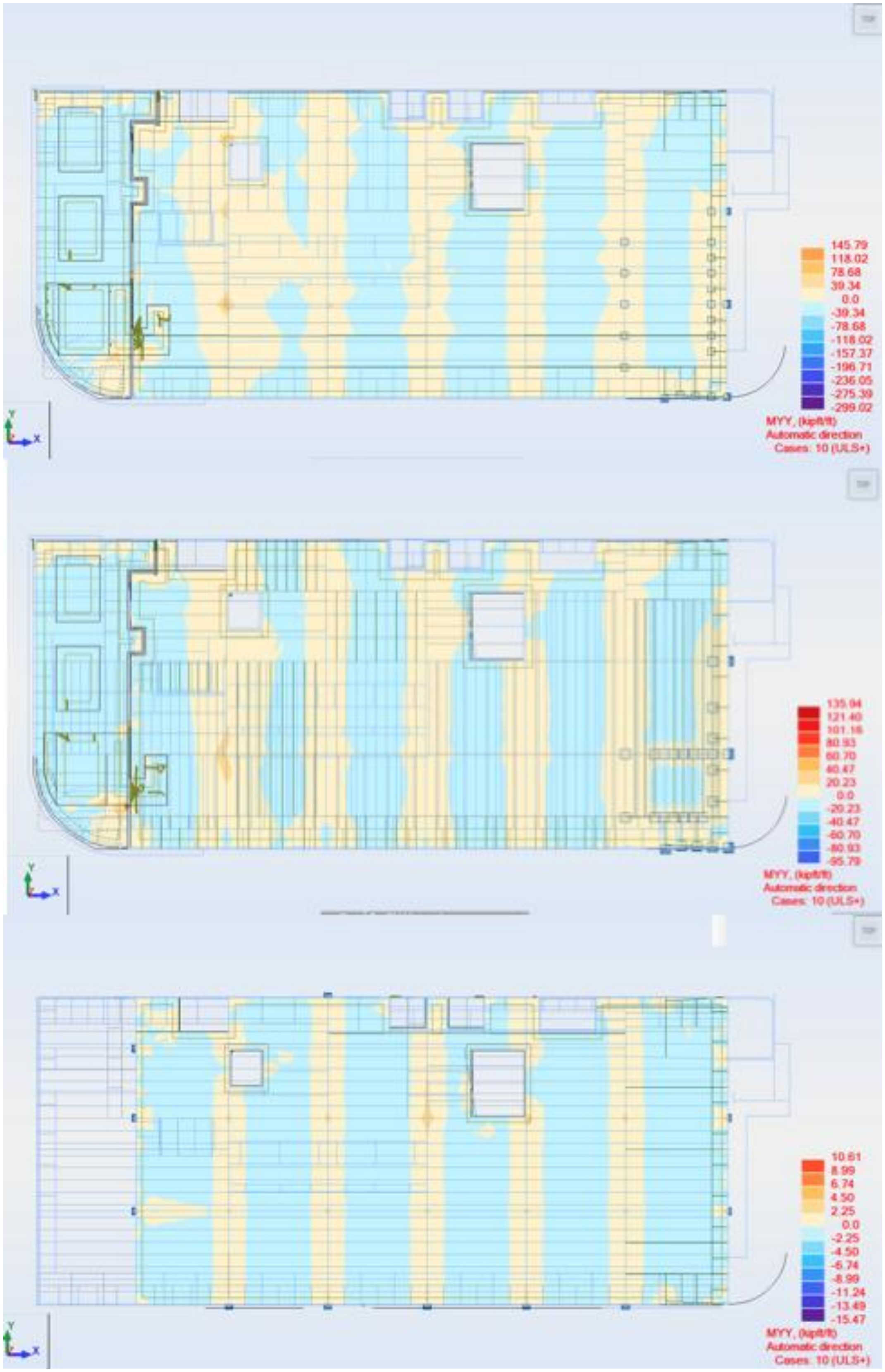


Figure 74: MYY Map Floor 2: Baseline (top), Open-Web (Middle), Precast (bottom)

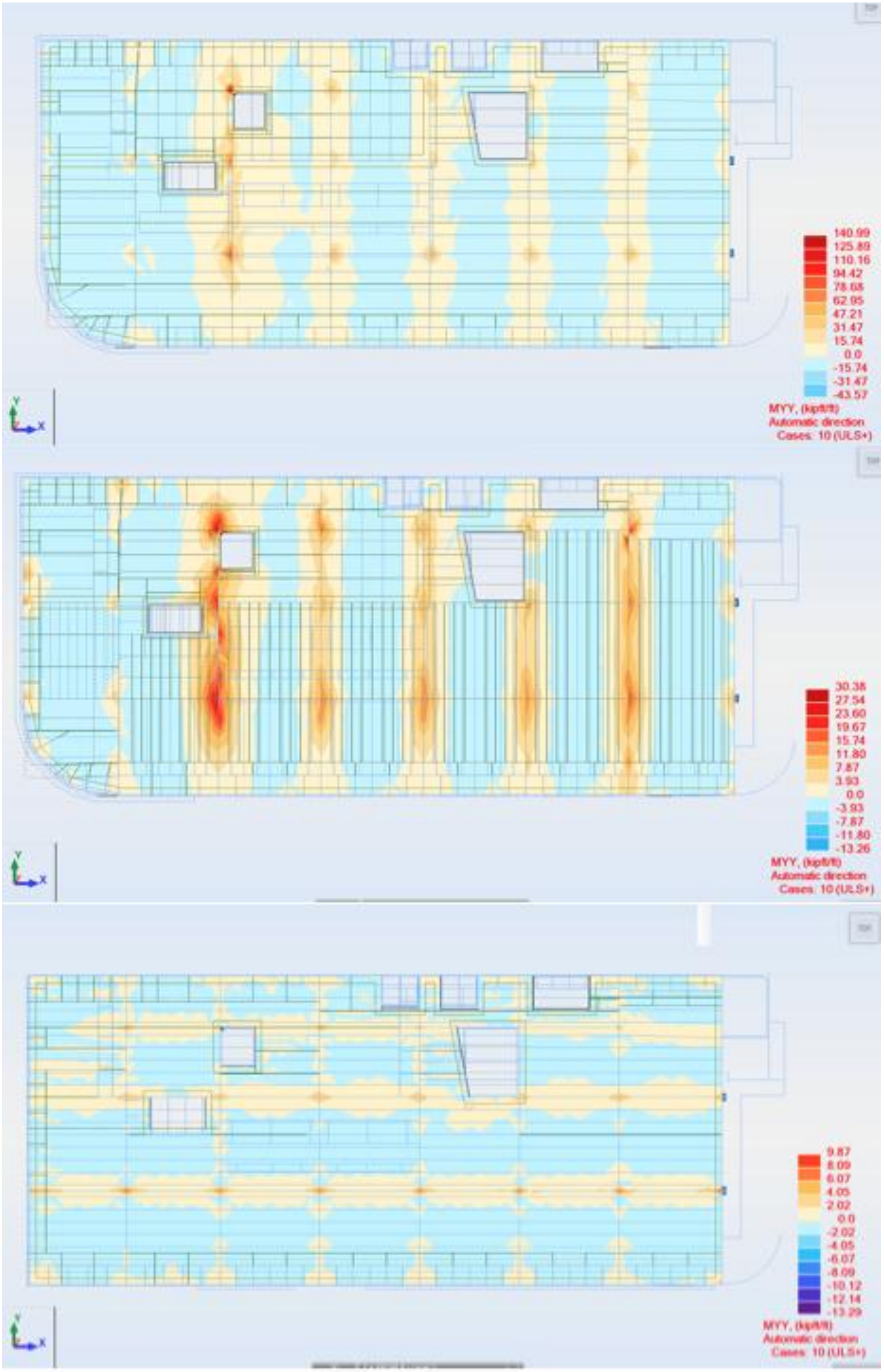


Figure 75: MYY Floor 3: Baseline (top), Open-Web (middle), Precast (bottom)

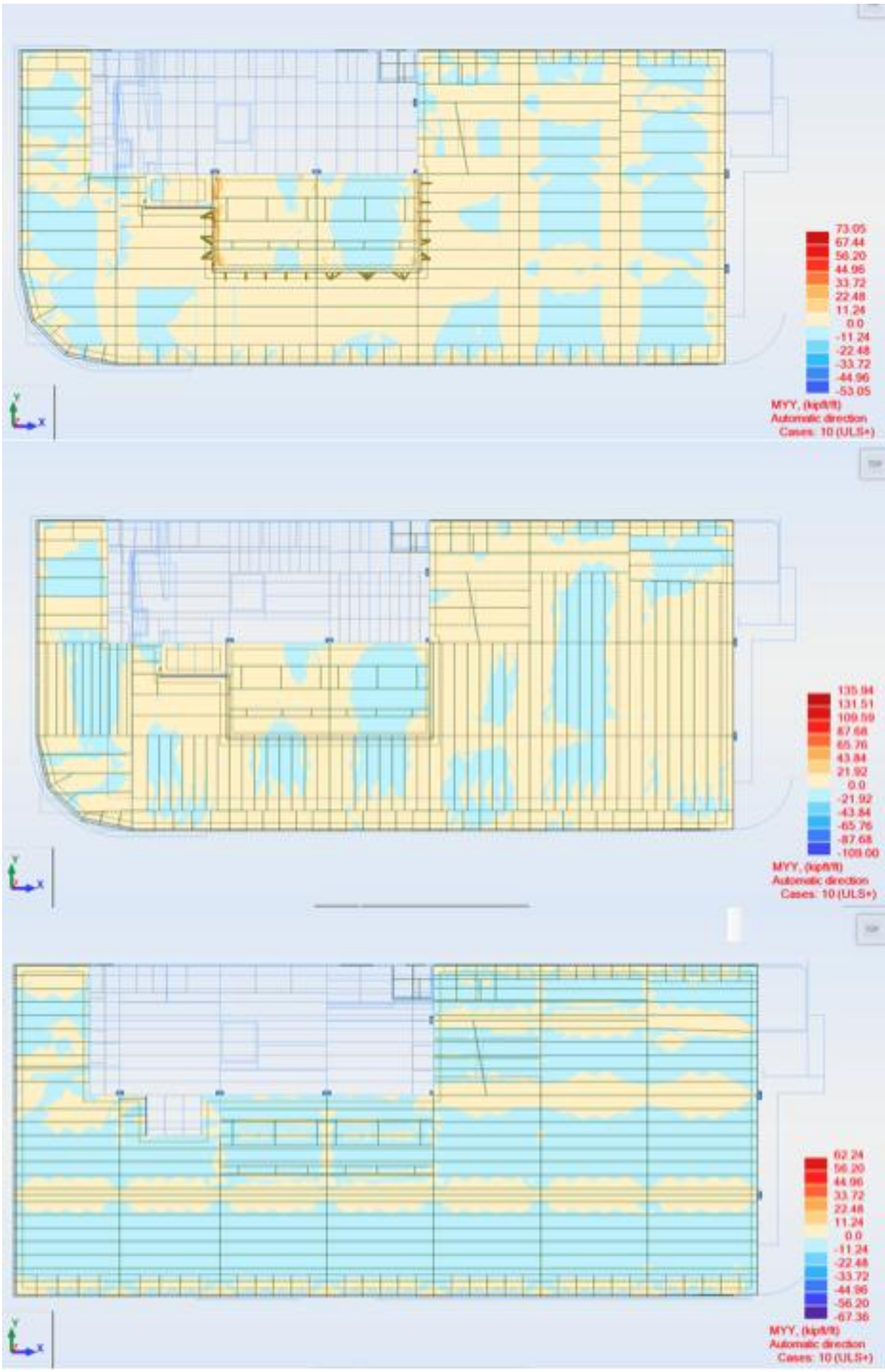


Figure 76: MYY Maps Roof: Baseline (top), Open-Web (middle), Precast (bottom)

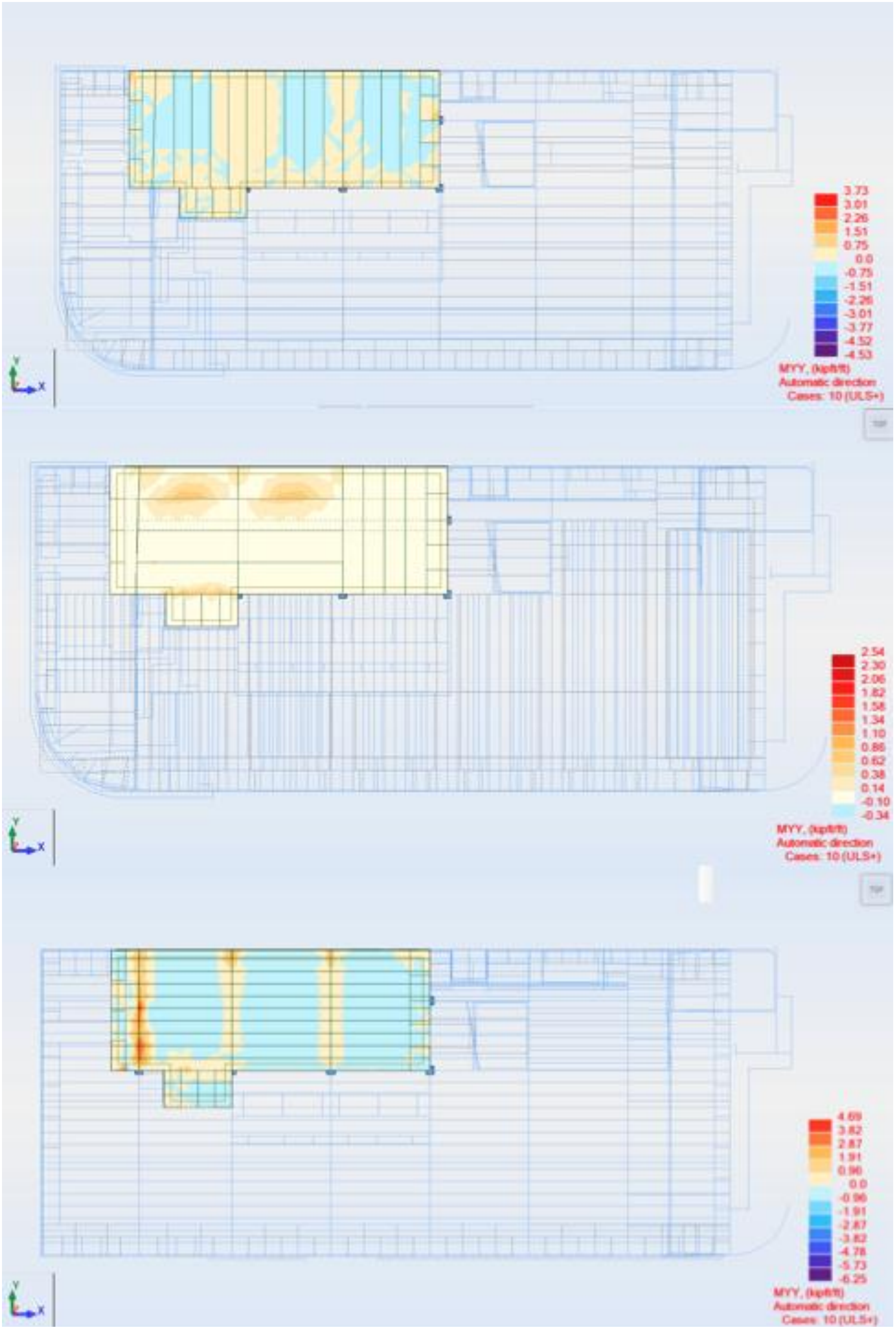


Figure 77: MYY Maps Mech Roof: Baseline (top), Open-Web (middle), Precast (bottom)

Looking at the Figures 74, 75, 76, and 77, one can see that the MYY maps produced by *Robot* are similar for the baseline and open-web bar joist model. However, the precast model seems to have significant differences, as previously mentioned the moment distribution direction changes.

6.2 Cost Evaluation

With both designs being structurally acceptable the cost is the next factor to consider when determining the best suited alternative design. Open-web bar joists are not as cost effective as the baseline design. By calculating the cost of using bar joists instead of W-shape sections, the cost of construction increases almost $400. Although this is a small amount, the focus of this project is to suggest alternatives that offer monetary savings. The second open-web design that was completed is approximately $2,200 more than the bid Gilbane received for the structural steel. Depending on the bid, wide flange beams may not be the more cost efficient model, as it depends on the available cost data. The RS Means estimate for wide flange beams would cost approximately $30,000 more than the RS Means estimate for the open-web bar joist design. Along with this, the bid package gives a cost per ton of steel at $4779.38, and the RS Means estimate at $4,883. With open-web joists replacing the wide flange beams, the cost per ton goes down to $4,658.06.Although using the first design has a lower cost per ton of steel than Gilbane's bid, the amount of steel needed for the additional bar joists makes this difference negligible. Cost comparison of each alternative design can be seen below in Table 13.

Precast planks on the other hand have proven that they are a cost effective design for the St. Vincent's Cancer Center. By calculating the cost for hollow core precast slabs with a reduction of W-shaped sections, the cost of construction decreases almost $95,000. The only downfall of using precast slabs is running plumbing and HVAC systems through the building. Through talking with Vin Parente, precast slabs are not generally used with building construction and are generally used in parking garages and large warehouses. This is because holes would have to be drilled through the planks in order to run MEP systems through the building. This means that an added cost would need to be evaluated depending on how many holes would be need in the building. The cost for these holes was not calculated as a definite number of holes were not known. Along with this, the cost of steel per ton increased from $4,779.38 from Gilbane's estimate to $4,889.67. This was because there is less weight in steel with the reduced number of W-shaped sections, but the cost for these sections is still very high. A comparison of CY costs could not be calculated as the CY of the precast planks was not known. A cost comparison can be seen below in Table 13 comparing the cost of each design to the bid package Gilbane received.

Table 13: Cost Comparison of Each Alternative Design

Design	Cost of Structural Steel	Cost of Concrete	Total Cost	Cost difference from Gilbane Bid
Baseline	$1,340,500.00	$1,889,729.00	$3,230,229.00	
First Open-Web Bar Joist	$1,340,854.69	$1,889,729.00	$3,230,583.69	($354.69)
Second Open-Web Bar Joist	1342674.06	$1,889,729.00	$3,232,403.06	($2,174.06)
Hollow Core Precast Plank	$1,144,251.62	$1,991,762.31	$3,136,013.93	$94,215.07

Therefore from this table it can be seen that the hollow core precast plank design is the only design that produces a cost savings. Although it is not known exactly how much it would cost to run the plumbing and HVAC systems through building and what effects this will have on the structural integrity of the planks. This cost would have to be considered before it was decided that this was an appropriate design.

6.3 Schedule Evaluation

Each of the alternative designs has time savings for the concrete and superstructure construction. The open-web bar joist designs improve the schedule for the superstructure by one day. With the steel framing being along the critical path, this has the advantage of improving the overall schedule of the whole project. This improvement of a critical path activity, even though it is only one day; can help to finish the project one whole day earlier. Due to this, the open-web bar joists would seem to be a viable option to improve the schedule of the project. In this case, the uniform construction design of open-webs would more likely be a better option of the two open-web designs as it allows the construction crews to not lose time looking for the correct bar joist, and allows them to develop a learning curve and know how to install the joist. This means the crews would increase productivity overtime, and can even improve on the schedule even more than just one day.

The design using hollow core precast planks on the other hand have a time saving of ten work days for concrete and superstructure schedules. Since there are multiple critical activities in these two pieces of the schedule, the project would likely finish sooner than the Gilbane's schedule. This ten day improvement would help to get the owner into the building much sooner and start to help the community. The only problem with using precast planks is the need for drilling holes to run plumbing and HVAC systems throughout the building. Due to this, the improvements in schedule might become negligible, as these holes could slow the project down. If there were no holes necessary for these systems, than this alternative design would be the best choice to improve upon Gilbane's design. A table of completion dates for all designs can be seen in Table 14.

Table 14: Completion Dates of All Designs

Concrete Design	
Baseline	Completion on Sep. 6
1st Open-Web Bar Joist	Completion on Sep. 6
2nd Open-Web Bar Joist	Completion on Sep. 6
Hollow Core Precast Planks	Completion on Aug. 23
Structural Steel	
Baseline	Completion on July 12
1st Open-Web Bar Joist	Completion on July 11
2nd Open-Web Bar Joist	Completion on July 11
Hollow Core Precast Planks	Completion on June 28

6.4 Constructability Evaluation

An important factor that cannot be quantified is the constructability of the designs. W-shaped sections with poured concrete slabs on each floor are the most common form of construction in the Northeast for medical facilities. This is due to the amount of plumbing and HVAC systems that are needed to run throughout the building as well as the large design loads for the building.

Out of the two open-web bar joist designs, the use of uniform joist sizes is obviously the better choice of the two when considering constructability. This is because the construction workers would not have to sort through a bundle of joists to find whichever particular size is needed and learn the installation of uniform joists faster. The original design created by SMMA for this project used open-web bar joists for the roof system (Vin Parente, personal communication, January 30, 2013). Due to the high snow drift loads though, this design was switched to W-shaped sections, where they could use less members to meet the required strength.

Precast planks are generally used in parking garages and warehouses as there is not a need for plumbing and HVAC systems to run throughout the building (Vin Parente, personal communication, January 30, 2013). In order to use precast planks in a medical facility holes would be drilled through the planks in order to run the necessary systems. These holes would add additional costs and time delays to the schedule to properly run the systems. Along with this, the structural capacity of the planks with these holes was not calculated, but the effects could prove that this design would not be capable of meeting the required design loads. The precast design also uses a rectangular building as opposed to one with a curved corner. It was not known how this would affect the procurement of the precast planks from the factory. Due to these things, a precast plank floor system would not meet the needs of this medical facility.

7.0 Recommendation with Five-Dimensional Modeling

Overall, each design met the required design loads given by SMMA for the building. The use of *Revit* allowed for rapid generation of members in each model and preparation of analytical designs that could be used for analysis in *Robot*. *Robot* provided a check of hand-calculations to determine the structural capabilities of the building. *Revit* enabled the team to export spreadsheets outlining each model's specific elements and members, which expedited cost analysis and scheduling for each alternative design.

The baseline model was used as the benchmark for each analysis. Both open-web bar joist designs showed that they were not as cost effective as the baseline design. Although this alternative produced a one day time savings for the schedule, the design would cost the owner more money which was not the goal of this MQP. The precast plank design on the other hand produced a time savings of ten work days, as well as a cost savings of $95,000. This design, however, would not be an appropriate design for a medical facility due to constructability issues. The lack of constructability of this design results from the need to install holes to run important plumbing and HVAC systems through each floor. Since the effects of these holes on structure, cost, and time are unknown, this design is not acceptable to use on the project. Therefore, the baseline design created by SMMA proves to be the best suited floor-system for building.

Once this was determined, a five-dimensional model was created using *Autodesk Navisworks*. The baseline *Revit* model was exported as a *Navisworks* file and integrated with the baseline *Primavera* schedule and costs, adding two more dimensions to the 3D model, resulting in a 5D model (see Appendix S). The 5D model is an excellent visual representation the structure being built; it depicts actually progression of construction by day and the increase in cost each day. Figures 78 to 83 below show various screenshots along the timeline of the 5D model.

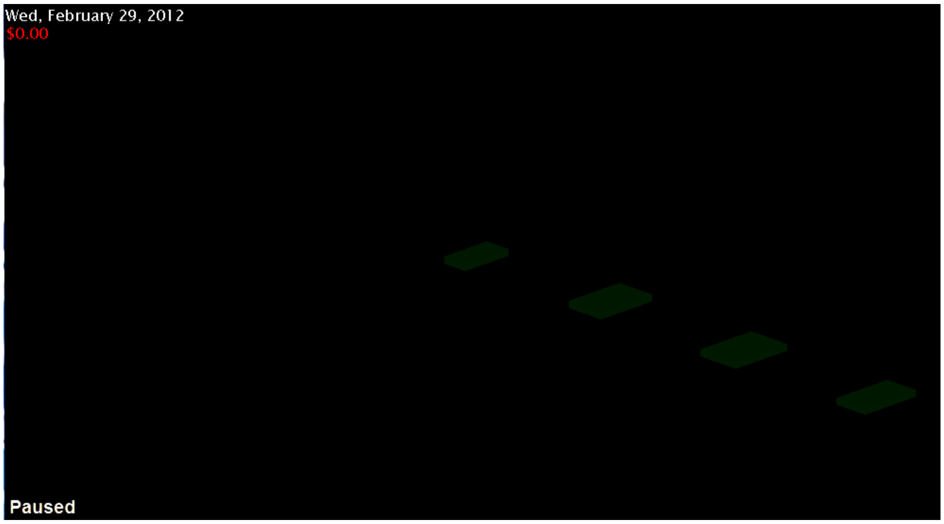


Figure 78: 5D Model (2/29/12, $0.00)

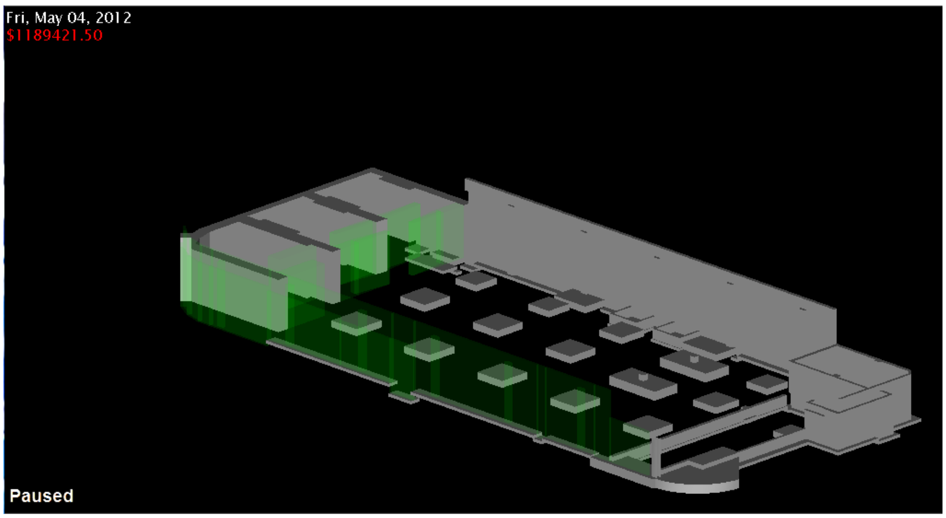


Figure 79: 5D Model (5/4/12, $1,189,421.50)

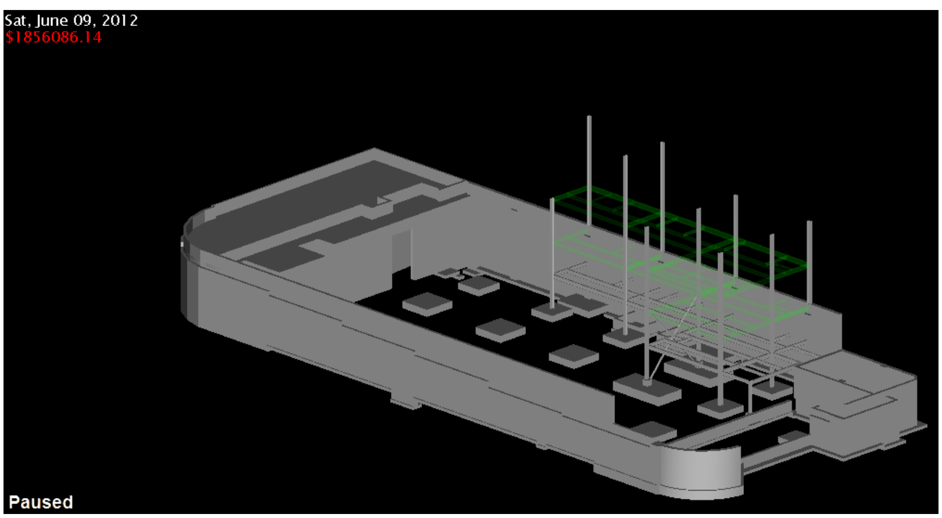


Figure 80: 5D Model (6/9/12, $1,856,086.14)

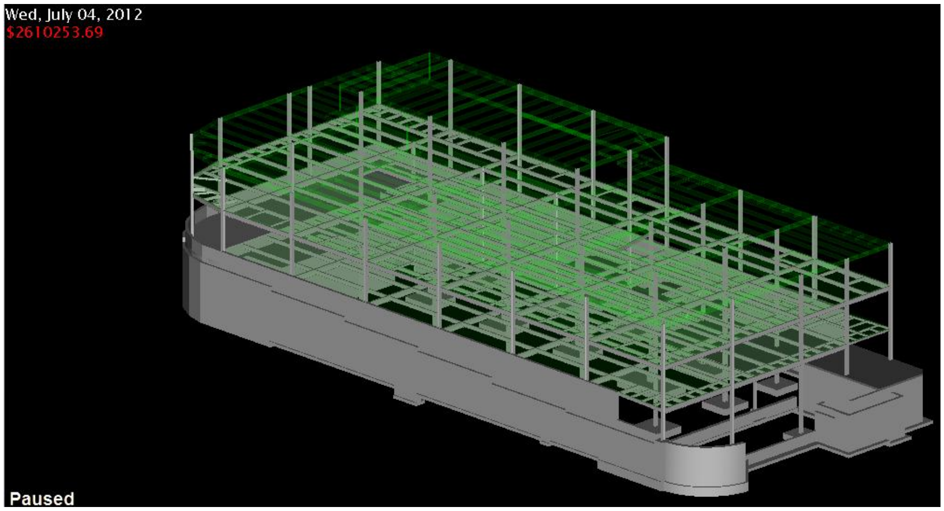


Figure 81: 5D Model (7/4/12, $2,610,253.69)

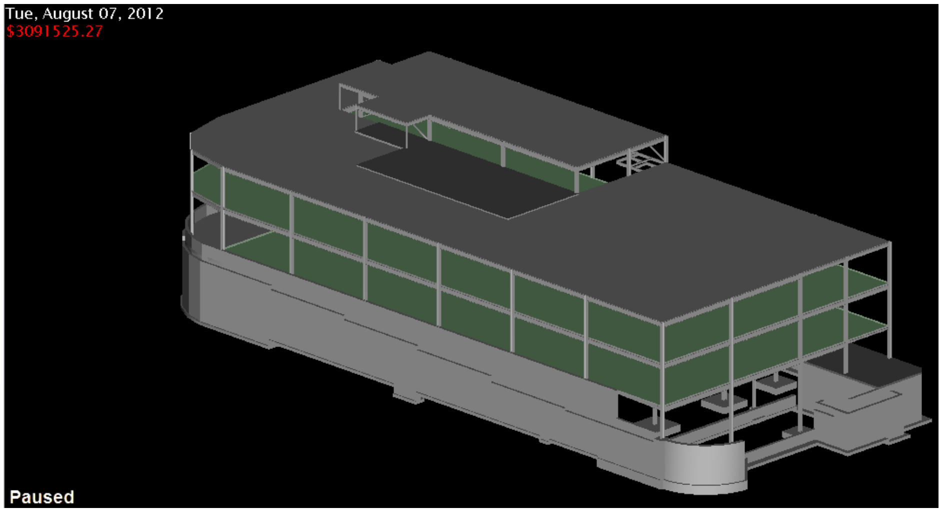


Figure 82: 5D Model (8/7/12, $3,091,525.27)

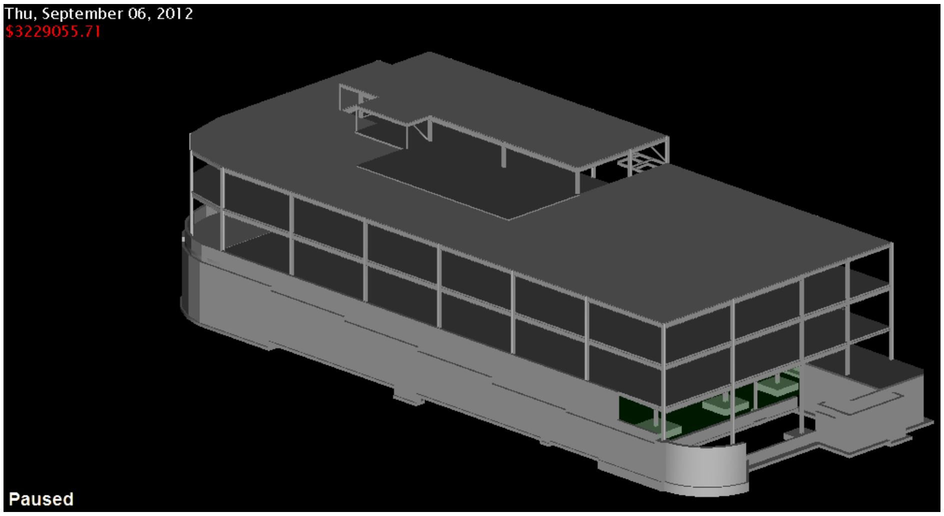


Figure 83: 5D Model (9/6/12, $3,229,055.71)

8.0 Conclusion

This MQP for the St. Vincent Cancer Center contains the design of two alternative floor systems and an analysis of each alternative design's impact on the project's cost and schedule. The St. Vincent Cancer Center shall suit the need for cancer treatment and research. With a low budget and no time to waste, multiple designs should be weighed to determine the design that is most beneficial in regards to time and cost.

By using *Revit*, *Robot*, and *Primavera* software a baseline and two alternative designs were created. This software was used to determine which design offered the lowest cost and shortest schedule. The alternative designs were proportioned to meet the design loads of the project, and the software helped to estimate the cost and schedule. *Robot* software was used to analyze the load and moment distribution through the floor systems. However, hand calculations verified that the *Robot* software was producing errors that related to the load paths. Despite the errors the software was used to make a comparison of the moment distribution throughout the floor designs. The use of *Robot* provided a deeper understanding and a great learning experience for the software and its interoperability with *Revit.*

The best way to compare the designs is cost and schedule. Both designs using open-web bar joists were more expensive than the baseline, but produced a one day time savings. The hollow core precast plank design produced a savings of approximately $94,000 and a time savings of ten work days when compared to the baseline. This design however was not as constructible as the plumbing and HVAC systems would need holes installed in the planks which could greatly increase the cost and time of the project. The alternative designs examined did not provide a favorable impact to the cost and schedule.

A 5-D model of the baseline design was created to better visualize the construction of the project over time in relation to cost and schedule. This visual aid helps to understand the construction process throughout time. A 5-D model combines the *Revit* model with the cost estimations and schedule to chart the progression of the project. Using a 5-D model aids the construction process as the flow of the whole project can be seen together.

Through this MQP two alterative floor systems were designed that could meet the structural needs of the requested building by St. Vincent Hospital. Although these designs proved to have some benefits, the baseline was proven to be the best design for the Cancer Center.

A medical facility like this is needed in today's society with a fast growing disease like cancer. As these buildings are being constructed it is interesting to see the how use of BIM could prove to be an even bigger tool during the construction process and how the integration of these software can be used for better engineering and construction areas of a project. It would be interesting to see how a building like this could be made more cost or time effective to help hospitals better meet the needs of the community. It would be interesting to explore how a 5-D model can be used on a construction site to improve decision making into engineering and construction on a project. This would be interesting as it has a practical purpose to and gives insight into the everyday work of a Project Manager.

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Appendix A: Proposal

LDA-1304
GFS-1302

St. Vincent Cancer Center: Construction Management through 5D Building Information Modeling with Alternative Floor System Designs

A Major Qualifying Project

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

in Civil Engineering by

John Dias

Kevin Griffin

Shaine Grogan

Greg Mollnow

Date: October 11th 2012

Approved:

Professor L. D. Albano

Professor G. F. Salazar

Abstract

As cancer treatment and research has expanded over the years, most hospitals have shown a need for a building to suit to this cause. St. Vincent has decided to build a Cancer Center in City Square development to meet these needs. We will be examining alternative floor system designs objective to speed up the process and lower the cost of the project. To assist our investigation, Building Information Modeling software will be utilized.

Capstone Design Statement

St. Vincent Cancer Center will be a state-of-the-art facility that will impact cancer patients in the Worcester area. However, there are many constraints that construction management teams will need to address. The capstone design requirement of our project will be met by exploring alternative floor system designs for St. Vincent Cancer Center located in the new City Square Development. A structural analysis of the alternative floor system designs under the design loads will be performed. We will also determine the effects of these alternative designs on their corresponding cost and scheduling. Building Information Modeling (BIM), Autodesk *Robot* and Autodesk *Revit*, as well as *Primavera* scheduling software will be used to aid in the design process.

In order to comply with the WPI MQP capstone design requirements, the following realistic constraints will be addressed during the completion of this project: economic, environmental, constructability, health and safety, and social.

The economic impact of the alternative floor system designs is the first constraint. A structural analysis will be performed to determine if the new floor systems will be adequate to support the required design loads of the facility. A cost and scheduling analysis will then be provided for most effective alternative design.

The environmental constraint will be met through exploring local environment variables. We will examine the effects that the St. Vincent Cancer Center project has on the surrounding City Square Development and traffic in Worcester.

The next constraint examined will be constructability of the alternative designs. This constraint will be met by researching the structural design of alternative floor systems and the effectiveness of building separation joints. We will determine if the constructability of these alternative designs will affect the cost and schedule of the project

The health and safety constraint will be met by determining whether the alternative floor system designs will be able to sustain the required design loads for the facility. We plan to determine if the designs will meet the building code criteria. Finally, we will also research safety factors that will occur during the construction phase.

The final constraint explored will be the social constraint. This constraint will be addressed throughout the duration of our project because the Cancer Center has a large impact on the community. Many patients in the Worcester area will be using this center for treatments. While creating alternative designs for the Cancer Center, we plan to ensure that the structure will be suitable for daily use by the patients.

1.0 Introduction

Older cities are being redeveloped to allow for new construction in crowded areas. Outdated buildings must either be retrofitted or torn down to make way for new facilities. This is especially true for the health and safety of society and the expansion of medical facilities. With the increasing needs for these facilities, the construction industry is called upon to carry out these projects.

Many disciplines contribute to a project, including the architect, construction manager, engineers, subcontractors, and owner. Every owner has a reason for their construction: some may fund a building's construction and later rent out space; others might have an expanding staff and need the extra work space. Medical facilities are expanding in order to make room for more patients and research space. The growing field of cancer research is in need of medical facilities because of the disease's rapid growth and fatality rate. Worcester, MA is in need of such a facility, but lacks the space around the metropolitan area. Located in the heart of Worcester, St. Vincent Hospital is looking to expand its cancer research and treatment but lacks the necessary space.

A new urban development in Worcester, called City Square, is currently being constructed adjacent to the main campus of St. Vincent Hospital. This development will provide the essential space needed for St. Vincent expansion. The St. Vincent Cancer Center will consist of three floors, for both cancer treatment and office space. The medical care space will consist of a radiation area for state-of-the-art equipment, waiting, exam, and recovery rooms for patients before and after procedures, and office space for the doctors of the facility. The construction of medical buildings can be a very particular process. There are thousands of decisions to be made during the design of a structure, which can greatly affect the budget and timeline of construction.

Space within the City Square development is limited therefore the Cancer Center must be built within feet of an existing parking garage.

The current structural design of the building consists of steel frame with elevated concrete slabs on steel decking. Our study will investigate two alternative designs to the floor system of the St. Vincent Cancer Center. We will compare these designs to recommend the more cost and time effective option. Our first design will use open-web bar joists in place of I-beams in the steel structure. Secondly, we will examine precast concrete planks to replace the cast-in-place concrete floor system. Using Building Information Modeling, our team will create 3D models of each structure and analyze them. The structures will be analyzed to determine adequate support and the effectiveness of each system. With each design, we will provide a cost-estimate and a schedule of activities. These elements can be combined with a 3D structure to make a 5D model. A five-dimensional model, which adds time and cost dimensions, helps to create a clear and complete overview of the project, with real-time simulation and visualization of the structure. We plan to evaluate each design using structural analysis, cost estimating, and scheduling.

Our study will also examine the effects of constructing a new building directly adjacent to an existing building. Expansion joints are commonly used to mitigate the effects of movement between buildings. We will explore expansion joints that can be used to connect St. Vincent Cancer Center to the existing parking garage.

The goal of this project is to investigate a suitable design that will meet the criteria of St. Vincent Cancer Center. The alternative floor system designs will be analyzed to ensure structural stability. The floor system designs will also have to satisfy the existing conditions relating to the building separation joint. Cost estimates will be made in conjunction with schedules to determine possible monetary and time savings for the project. Our evaluations will consider all these factors to provide an effective alternative structure that could potentially offer benefits to the project.

2.0 Background

This background examines the growing need for a Cancer Center at St. Vincent Hospital Worcester, MA. The section starts with a discussion of St. Vincent Hospital and the development of City Square. Following sections provide an overview of project management and structural designs. In several of these sections we discuss the application of computer software and Building Information Modeling in construction processes.

2.1 The History of City Square

On July 29th, 1971, the city of Worcester, Massachusetts officially became the home of the brand new 1,000,000 square foot Worcester Center Galleria (Huard, 2012). Attached to the Galleria, a 4,300-car parking structure was constructed with the anticipation of a large popularity for the new city development. At that time, that parking structure was the largest parking structure in the world. Figure 1 shows an aerial photograph taken of the Worcester Center Galleria parking structure.

Figure 84: Worcester Center Galleria parking structure (Telegram & Gazzete?, 1981).

Despite being one of the largest shopping retail venues in Worcester, the popularity of the new Galleria did not live up to expectations (Huard, 2012). Other local competitors and vendors gained the business of customers. The Galleria went through numerous name changes to go along with multiple remarketing efforts. However, the fate of the mall took a turn for the worse with the opening of the nearby Wrentham Village Premium Outlets in 1997. After nine more years of struggling to keep tenants, the Galleria, which in past years was renamed the Worcester Common Outlets, was closed in 2006. Upon the mall's closing, property owner Berkeley Investments put together a redevelopment plan for a pedestrian friendly, mixed use development called City Square.

2.2 The Future of City Square

The development of City Square has been a project that most Worcester residents would consider long overdue in light of the failure of the existing shopping mall. Partners Opus Investments, Hanover Insurance Group (the real estate arm), and Leggat McCall will be providing substantial financial assets, overall project scope, and most of all, hope for the run down area of Worcester(City of Worcester, 2012). With removal of the existing mall and parking structure, the 20 plus acres will be the new home of upscale urban residences, restaurants, clubs, retails shops, entertainment venues, and state of the art medical, life sciences, and professional office space. When construction of the new Square is completed, it is expected to have a cost of approximately $563 million dollars making the Worcester City Square project the largest public/private development project in Massachusetts history with the exception of the City of Boston.

The first phase of the project includes the construction of the 214,000 square foot Unum Building, and the 66,000 square foot Saint Vincent Cancer Center (City of Worcester, 2012). The

Unum project is primarily funded by the Unum Group, and construction is expected to be approved for LEED-Silver certification. The Unum Group expects for the building to be occupied by January 2013. Saint Vincent Hospital will invest $21 million, and the expected date of completion is the spring of 2013. Early construction phases of Saint Vincent Cancer Center can be seen in Figure 2.

Figure 85: Saint Vincent Cancer Center in Early Construction Phases. (City of Worcester, 2012)

2.3 St. Vincent Hospital

Saint Vincent Hospital was originally found by the Sisters of Providence in 1893. At first, the hospital was a Catholic community-based hospital and was named after the patron saint of the Sisters' order, Saint Vincent de Paul (St. Vincent Hospital, 2012). Pictured in Figure 3, the hospital contained twelve beds and had a capacity to care for a total of 30 patients.

Figure 86: Saint Vincent Hospital in 1893 (St. Vincent Hospital, 2012)

After moving to various to new locations and settling into larger facilities, Saint Vincent opened a nursing school in 1900(St. Vincent Hospital, 2012). A larger facility was constructed on Providence Street in 1922 strictly for the nursing school. The school had great success but closed in May of 1988. More building expansions occurred in: 1964 with a five story service wing, 1965 with the Bishop Wright Pavilion (containing a 51-bed psychiatric ward, 45-bed maternity section, and 52-bed surgical floor), 1969 the Anderson Building (housing the Data Processing Center), 1970 the Rose Building built for laboratory and research, and 1984 with the amphitheater and modern medical library.

In 1990, Saint Vincent Healthcare System formed after the hospital was corporately recognized in 1983 (St. Vincent Hospital, 2012). At this time, the hospital merged with Fallon Healthcare System, creating the first vertical integrated healthcare facility, which offers a broad range of patient care and support services, in the Worcester area. In recent years, the current hospital was renamed Worcester Medical Center. In 1997, construction of the Worcester Medical Center commenced and was completed on April 1, 2000. A rendition of the completed project is in 1990, Saint Vincent Healthcare System formed after the hospital was corporately recognized in 1983 (St. Vincent Hospital, 2012). At this time, the hospital merged with Fallon Healthcare System, creating the first vertical integrated healthcare facility, which offers a broad range of patient care and support services, in the Worcester area. In recent years, the current hospital was renamed Worcester Medical Center. In 1997, construction of the Worcester Medical Center commenced and was completed on April 1, 2000. A rendition of the completed project is shown in Figure 4. Vanguard Health System purchased the state-of-the-art facility in 2005 and continues to uphold the Catholic foundation in which the hospital was first built.

Figure 87: St. Vincent Medical Center (St. Vincent Hospital, 2012)

2.4 Project Management

Design-Build (D-B) projects are becoming a more common form of construction. This method allows the owner to hire a single entity for design and construction and to help the project move along faster, because the construction of the project can begin before the structure is fully designed. This method is selected when the schedule is most important, cost is secondary, and the scope is not entirely defined (Oberlender, 2000). Although in D-B projects a firm is generally hired to design and then manage the construction of the project, with this project

Gilbane (a construction management firm) has been hired by St. Vincent Hospital to lead the Design-Build entity and subcontract the design, as well as to manage the project.

2.4.1 Organizational Breakdown

The St. Vincent Cancer Center project is a design-build project. This usually means that owner hires a design-build firm to coordinate the design and construction of the project (Oberlender, 2000). Fast-tracking is a method used when the full design of the project is not complete, but construction can begin; future parts of the project can be designed and adjusted accordingly based on how the initial construction phases go. Fast-tracking has the advantage of a reduced completion time, which will save the owner time and reduce construction costs. The owner often has more control over design revisions while construction is underway because the design is still being adjusted for finish phases. There are several contractual arrangements for financial compensation to the construction management firm. Many times, a cost reimbursable contract is used because the scope is not well-defined and an accurate budget cannot be estimated. In other cases, including the St. Vincent Cancer Center, there is a well-defined scope, and a guaranteed maximum price contract (GMP) can be used. Figure 5 shows the contractual arrangement and organizational breakdown for the St. Vincent project.

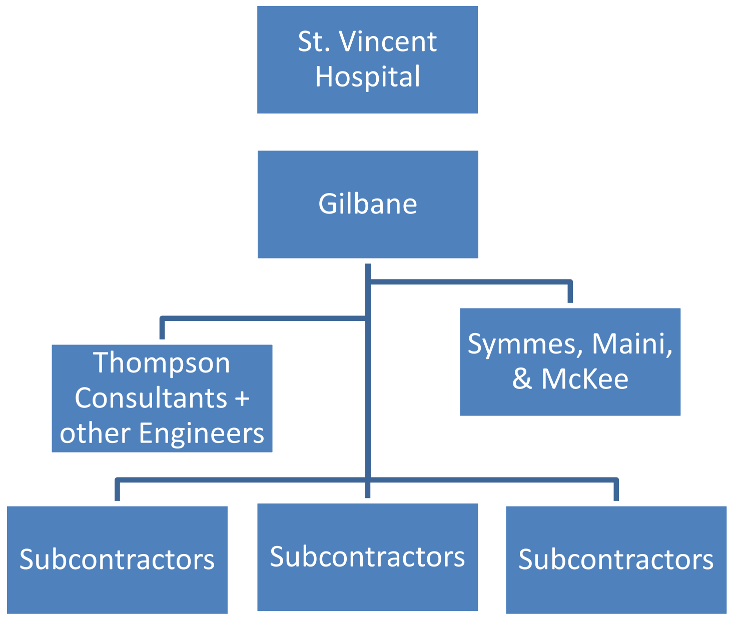


Figure 88: Organizational Breakdown for St. Vincent Cancer Center

The owner of the project is St. Vincent Hospital. Gilbane leads the design-build entity for the job. Working on the design team are Symmes, Maini, & McKee Associates and Thompson Consultants, among other engineers. There are eighteen subcontractors on the job, including JL Marshall & Sons, Inc. for concrete and United Steel for steel. A complete list of subcontractors and engineers can be found in Appendix B (Gilbane, 2012).

2.4.2 Cost

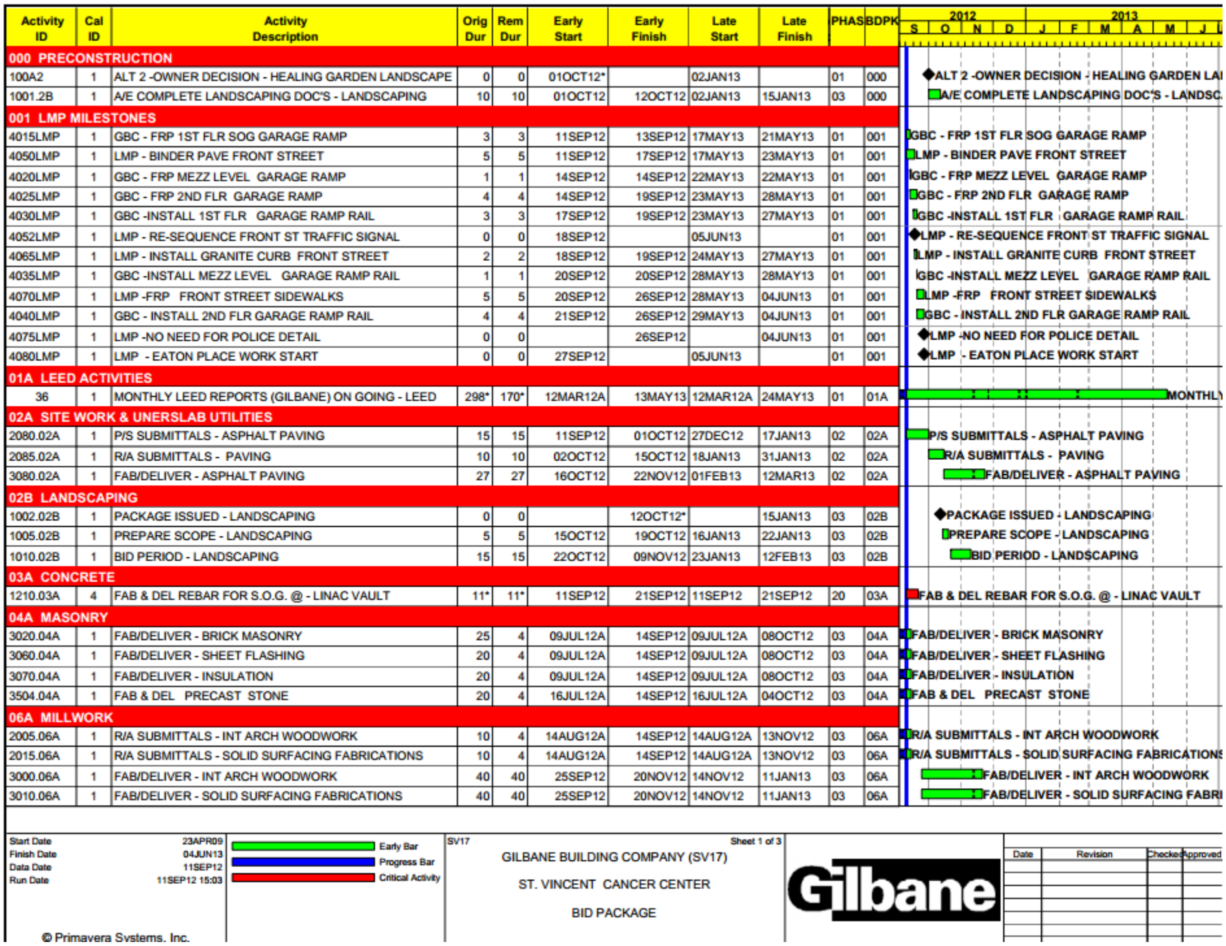
This project is a contractor led design-build. This means that they will take the lead and work to finish the project in the best interest of the owner. The owner selected a Contractor (Gilbane) to lead this process. From here, based on SMMA design, Gilbane created bid packages with individual scopes of work for different subcontractors. With these packages completed, drawings and contract documents were sent to different subcontractors to bid on the job. Once the subcontractors were awarded the contracts, the actual cost of the project can be determined. Due to complexity of projects, the actual cost cannot be determined for months. In order to get the project off the ground most of these subcontractors must be awarded early, but other non-critical activities can be awarded later in the process.

The Cancer Center is a Guaranteed Maximum Price (GMP) contract. This means the Design-Builder agreed to a fixed completion date and a maximum price for the project. In order to ensure project completion by the fixed date, the owner will have liquidated damages in the contract. Liquidated damages are a penalty that the CM must pay every day the project exceeds agreed upon date. The GMP can be set before or after subcontractor bids, but waiting to receive bids makes a more accurate GMP. This gives a more accurate price and a smaller chance for change orders. The GMP for the Cancer Center is $14,220,858 (Gilbane, 2012).

2.4.3 Schedule

Primavera is a software program that is most commonly used to create a schedule. This program has the capabilities to track all of the important aspects of a schedule, such as duration of activities, cost, and relationships between activities. *Primavera* can be used to track contracts, risk management, and document control items. This is done through integration with other programs like E-Business and JD Edwards Enterprise One (Oracle, 2011a). It can track contract summary to date, change orders, and payment processing rates. For risk management, the program can calculate confidence levels based upon common pitfalls that are associated with activities in the schedule and risk factors that are predefined in the program. Pertaining to document control, the program allows the monitoring of communication processes such as number of resolved and unresolved issues, actions that must be taken to keep the track on schedule, and RFI and submittal turnaround rates (Oracle, 2011b).

Primavera is a Construction Project Management software that can be used to order tasks of the project. This means that the program allows the user to set an order of precedence in order to manage the critical path of the project. The critical path method (CPM) is generally implemented in many construction schedules. This method sets chains of activities with no float time in order, which is done to accurately determine the end date of the project. If these activities are not completed on time, then the completion date of the project will be pushed back.



Activity ID	Cal ID	Activity Description	Orig Dur	Rem Dur	Early Start	Early Finish	Late Start	Late Finish	PHAS	BDPK
000 PRECONSTRUCTION										
100A2	1	ALT 2 -OWNER DECISION - HEALING GARDEN LANDSCAPE	0	0	01OCT12*		02JAN13		01	000
1001.2B	1	A/E COMPLETE LANDSCAPING DOC'S - LANDSCAPING	10	10	01OCT12	12OCT12	02JAN13	15JAN13	03	000
001 LMP MILESTONES										
4015LMP	1	GBC - FRP 1ST FLR SOG GARAGE RAMP	3	3	11SEP12	13SEP12	17MAY13	21MAY13	01	001
4050LMP	1	LMP - BINDER PAVE FRONT STREET	5	5	11SEP12	17SEP12	17MAY13	23MAY13	01	001
4020LMP	1	GBC - FRP MEZZ LEVEL GARAGE RAMP	1	1	14SEP12	14SEP12	22MAY13	22MAY13	01	001
4025LMP	1	GBC - FRP 2ND FLR GARAGE RAMP	4	4	14SEP12	19SEP12	23MAY13	28MAY13	01	001
4030LMP	1	GBC -INSTALL 1ST FLR GARAGE RAMP RAIL	3	3	17SEP12	19SEP12	23MAY13	27MAY13	01	001
4052LMP	1	LMP - RE-SEQUENCE FRONT ST TRAFFIC SIGNAL	0	0	18SEP12		05JUN13		01	001
4065LMP	1	LMP - INSTALL GRANITE CURB FRONT STREET	2	2	18SEP12	19SEP12	24MAY13	27MAY13	01	001
4035LMP	1	GBC -INSTALL MEZZ LEVEL GARAGE RAMP RAIL	1	1	20SEP12	20SEP12	28MAY13	28MAY13	01	001
4070LMP	1	LMP -FRP FRONT STREET SIDEWALKS	5	5	20SEP12	26SEP12	28MAY13	04JUN13	01	001
4040LMP	1	GBC - INSTALL 2ND FLR GARAGE RAMP RAIL	4	4	21SEP12	26SEP12	29MAY13	04JUN13	01	001
4075LMP	1	LMP -NO NEED FOR POLICE DETAIL	0	0		26SEP12		04JUN13	01	001
4080LMP	1	LMP - EATON PLACE WORK START	0	0	27SEP12		05JUN13		01	001
01A LEED ACTIVITIES										
36	1	MONTHLY LEED REPORTS (GILBANE) ON GOING - LEED	298*	170*	12MAR12A	13MAY13	12MAR12A	24MAY13	01	01A
02A SITE WORK & UNERSLAB UTILITIES										
2080.02A	1	P/S SUBMITTALS - ASPHALT PAVING	15	15	11SEP12	01OCT12	27DEC12	17JAN13	02	02A
2085.02A	1	R/A SUBMITTALS - PAVING	10	10	02OCT12	15OCT12	18JAN13	31JAN13	02	02A
3080.02A	1	FAB/DELIVER - ASPHALT PAVING	27	27	16OCT12	22NOV12	01FEB13	12MAR13	02	02A
02B LANDSCAPING										
1002.02B	1	PACKAGE ISSUED - LANDSCAPING	0	0		12OCT12*		15JAN13	03	02B
1005.02B	1	PREPARE SCOPE - LANDSCAPING	5	5	15OCT12	19OCT12	16JAN13	22JAN13	03	02B
1010.02B	1	BID PERIOD - LANDSCAPING	15	15	22OCT12	09NOV12	23JAN13	12FEB13	03	02B
03A CONCRETE										
1210.03A	4	FAB & DEL REBAR FOR S.O.G. @ - LINAC VAULT	11*	11*	11SEP12	21SEP12	11SEP12	21SEP12	20	03A
04A MASONRY										
3020.04A	1	FAB/DELIVER - BRICK MASONRY	25	4	09JUL12A	14SEP12	09JUL12A	08OCT12	03	04A
3060.04A	1	FAB/DELIVER - SHEET FLASHING	20	4	09JUL12A	14SEP12	09JUL12A	08OCT12	03	04A
3070.04A	1	FAB/DELIVER - INSULATION	20	4	09JUL12A	14SEP12	09JUL12A	08OCT12	03	04A
3504.04A	1	FAB & DEL PRECAST STONE	20	4	16JUL12A	14SEP12	16JUL12A	04OCT12	03	04A
06A MILLWORK										
2005.06A	1	R/A SUBMITTALS - INT ARCH WOODWORK	10	4	14AUG12A	14SEP12	14AUG12A	13NOV12	03	06A
2015.06A	1	R/A SUBMITTALS - SOLID SURFACING FABRICATIONS	10	4	14AUG12A	14SEP12	14AUG12A	13NOV12	03	06A
3000.06A	1	FAB/DELIVER - INT ARCH WOODWORK	40	40	25SEP12	20NOV12	14NOV12	11JAN13	03	06A
3010.06A	1	FAB/DELIVER - SOLID SURFACING FABRICATIONS	40	40	25SEP12	20NOV12	14NOV12	11JAN13	03	06A

Figure 89: Primavera Schedule for Cancer Center (Gilbane, 2012)

Pictured above in Figure 6, is an example of a *Primavera* schedule (Gilbane, 2012). The schedule is generally broken down into different groups based on the trade, level of building, phase of construction, etc. Figure 6 is a schedule from Gilbane broken down by trade for the St. Vincent Cancer Center. The columns on the left contain the activities along with each activity's original duration, remaining duration, early start, early finish, late start, late finish, phase, and bid package. The durations, starts, and finishes are the most important and are what define the schedule's timeline. Any delays or time gains can be recorded and used to move tasks around on the fly. Another key feature is assigning activities to follow other specific activities, which are called successors. For example, the concrete floor slabs cannot be placed until the metal decking is ready, so if the metal deck is laid early and recorded in *Primavera*, the program will show that the concrete can be placed early. The right side of the schedule uses a bar chart to show the progression of the project, with the vertical blue line representing the current day.

Float is another important aspect of a schedule (Oberlender, 2000). There are two different types of float: total float and free float. Total float is the number of days one activity can be delayed and there will be no affect on the final completion date of the project. Free float is the number of days a single activity can be delayed that would not affect the earliest start time of the next activity in the schedule. It is important to monitor and calculate both of these floats, especially total float, to complete the project on time. If total float is exceeded, the activity has the potential to become a critical activity and affect the completion time of the project. Schedules can also display relationships that are established between the activities

A final aspect that makes a schedule a valuable tool for construction management is the capability to aid in the computation of Earned Value Analysis (EVA) of a project (Oberlender, 2000).. EVA is a comparison of the cost of the projected work up to a certain point and the actual cost of work that has been completed. This analysis can be used to determine if the cost, schedule, and work accomplished are progressing in accordance with the plan. With an up-to-date schedule, the quantity of work completed can be determined and compared to previously projected work. This analysis is used to evaluate both cost and schedule. Gilbane tracks the manpower to assess the progress of the project instead of the Earned Value Analysis as a type of project control.

2.4.4 Building Information Modeling (BIM) in Project Management

Building Information Modeling, or BIM, has revolutionized the construction industry by allowing firms to "simulate project's many phases or individual components, thus minimizing the chances for error and reducing the cost of a project" (O'Brien, 2010). The basics of BIM revolve around 3D modeling software, such as Autodesk *Revit*, but this is only the first of many pieces. Large amounts of building information from all parts of a project can be coordinated into the model to visually display relationships with other portions of the project (Smith, 2009). The architect can create the initial building model. The structural engineer can add in structural members. The civil engineer can use GPS coordinates and other terrain tools to show the building in its exact geological location. The electrical, plumbing, and HVAC subcontractors can add light fixtures, pipes, and ductwork to create specific systems. Different programs can take each piece of the model and look for errors and clashes; further perfecting the model before construction begins or solving problems that might occur in the field. Figure 7 illustrates all the tasks associated with BIM software.

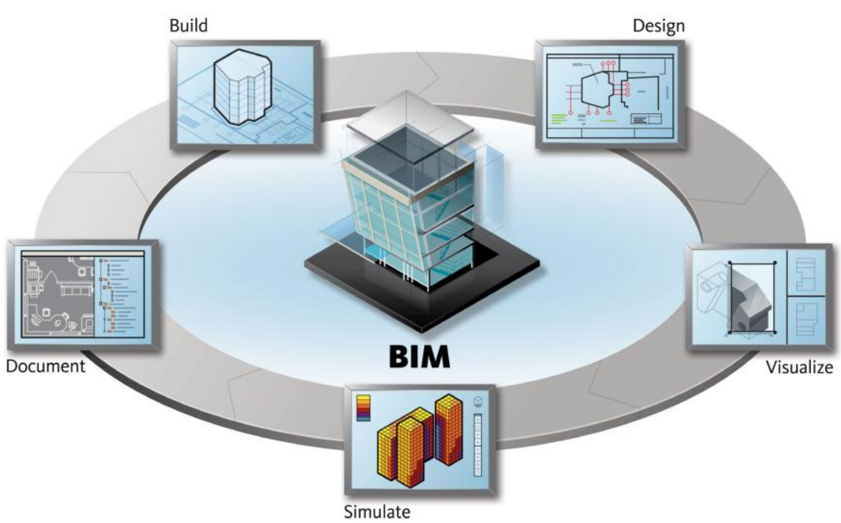


Figure 90: Application and Integration of BIM in Design and Construction (Autodesk, 2012a)

The project management team can go beyond visual models and assign costs to each item in the building (Smith, 2009). Each part of the model can also be given a phase and the model can be tracked on a timeline to see what tasks should be completed by a certain date. Models that display schedule are often called 4D models, and models that display both schedule and cost are often called 5D models. A 4D model simulates the actual building of a project in real time, which allows the owner and contractors to visualize the logistics of construction. A 5D model adds the element of cost to depict the budget progression at certain milestones of construction. Additional tools are available to analyze a building's carbon footprint, predict energy use, and evaluate structural capacity (Autodesk, 2012a). The possibilities for BIM are almost limitless.

Autodesk Revit

Autodesk *Revit* is considered one of the principal BIM software packages ("Research and Markets," 2011). *Revit* has gained popularity for its user-friendliness, online support and community, and real-world capabilities. The program allows users to create 3D models of whole projects, ranging from the bricks to the columns to the piping (Autodesk, 2012a). Information can also be imported to represent the actual geological location and terrain of a project.

There are three branches of the software: architecture, structure, and systems. Architecture features allow building designers to create 3D models of projects, which can show owners what a building will look like, and it also helps with project coordination. Some of the construction tasks that are associated with the architecture features include building walls, doors, windows, finishes, furniture, landscaping, and site, choosing colors and materials to be used, and various other commands. The systems commands focus on the mechanical, electrical, and plumbing (MEP) components (Autodesk, 2012b). Subcontractors can use the program to coordinate with each other to ensure that there are no clashes where they plan to run conduit, piping, duct, etc. Finally, structure capabilities are more focused on the actual parts that support the building. This includes the structural steel, trusses, slabs, metal decking, and foundation. Structural engineers can use the software to create models of assemblies and simulate, analyze, and design more structurally sound buildings.

Autodesk Navisworks

Autodesk *Navisworks* is a coordination program that is used by many construction managers that use BIM software. The CM can use *Navisworks* to combine all the *Revit* models from each trade so that the complete project can be analyzed in one environment (Autodesk, 2010b). This is extremely effective for clash detection, which will find areas where multiple models have an element in a given area ("Autodesk Announces Availability," 2009). These clashes can be fixed before construction is underway; saving time that might have been wasted in the field.

Navisworks can also be an effective tool for simulating a project ("Autodesk Announces Availability," 2009). The user can import schedules from other programs, including *Primavera*, and assign costs for each item in the model; the two features make a 3D model into a 5D model. A model with five dimensions shows a simulation of the project developing over time and increasing in cost. The building model can show exactly what will be completed at any specific date and the cost that will represent progress up to that point. The 5D model is an excellent tool for all members of a project (Autodesk, 2010b). The owner can see the project being built over time and how much money will be spent. The construction manager can plan logistics of the project, including traffic, shipments, and schedule. The subcontractors can understand when their trades will be working. Figure 8 below shows the project viewing mode where the user can control a virtual person and explore the project at any point.

Figure 91: Project Viewing Mode (Autodesk, 2010b)

2.5 Floor Systems

In modern construction a large percentage of buildings are erected using a combination of reinforced concrete and structural steel (McCormac & Csernak, 2012). In steel-frame buildings concrete floor slabs of one type or another are used. The current design of St. Vincent Hospital Cancer Center is a steel frame with concrete on steel decking. The concrete floor systems are strong and have good fire and acoustical ratings; however the construction is expensive, heavy, and may require formwork. The steel frame system offers advantages of constructability, a quick erection, and can increase floor space, as columns are rather small in comparison to concrete columns. In designing a floor system for steel framed building there are many options for the type of concrete flooring and the steel support system of these floors. It is crucial in designing a floor system to use a system that provides fire rating desired, sound and heat transmission, support for dead weight of floor and ceiling situation below, and facility of floor for concealment of MEP.

Each type of floor system offers different advantages and disadvantages that may have a significant effect on the cost and schedule of a project. This means it is of utmost importance to choose a floor system that best satisfies the requirements of the intended building.

2.5.1 Bay Design

Low-rise buildings are buildings that are not very tall in respect to their lateral dimensions (McCormac & Csernak, 2012). There are four groups of steel frames that are used for buildings. The types are bearing-wall construction, skeleton construction, long-span construction, and combination steel and concrete framing. For this project, we will examine skeleton construction frames. The loads in these frames are transmitted to the foundations by a framework of steel beams and columns. All of the dead loads and live loads of these buildings are transferred through the framing system to the foundation.

Concrete floor slabs are almost always used with steel-framed buildings (McCormac & Csernak, 2012). The concrete offers exceptional strength, as well as great fire ratings as concrete is noncombustible and provides an insulative barrier between building floors. On the other hand, the concrete floors are heavy, they require reinforcements, and they can be difficult to make waterproof. The following is a list of common concrete floor systems that are used on steel frames:

8. Concrete slabs supported with open-web steel joists
9. One-way and two-way reinforced concrete slabs supported on steel beams
10. Concrete slab and steel beam composite floors
11. Concrete-pan floors
12. Steel-decking floors
13. Flat slab floors
14. Precast concrete slab floors.

There are many factors that contribute to the selection of the concrete floor system to use, such as loads, fire rating, sound and heat transmission, ceiling types, MEP concealment, time required to construct, etc. A floor system is chosen by the architect that best meets these factors, while at the lowest construction cost. For the St. Vincent Cancer Center an I-beam floor system was chosen with concrete on steel decking. There are many alternatives to this system that may offer advantages, but at the same time affect the cost of the project. The goal of an architect is to design a building that meets the specified requirements, while choosing from a multitude of designs.

2.5.2 Open Web Bar Joists

Open-web steel joists are a very common practice for small steel-frame buildings (McCormac & Csernak, 2012). These joists are small parallel chord trusses that consist of members of bar, small angles, or other rolled steel shapes, as displayed in Figure 9.Steel decking is then usually attached to the joists using welding or self-drilling/self-tapping screws. The concrete is then placed on top of the steel deck. It is a very economical and lightweight type of concrete floor system.

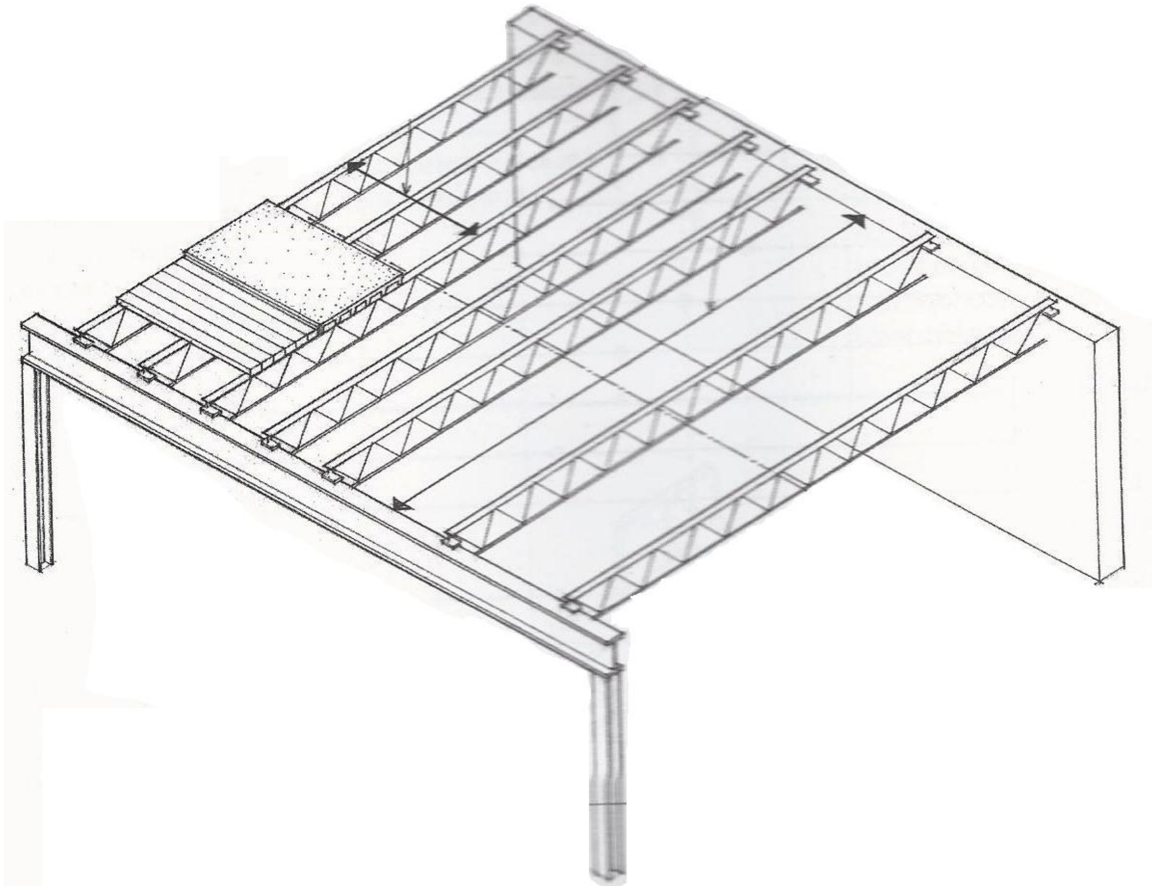


Figure 92: Open-Web Bar Joists (Ching, 2008)

Open-web steel joists are ideal for relatively light loads and structures that do not have much vibration (McCormac & Csernak, 2012). They are well suited for low-level buildings, but they can be used for tall buildings too. The bar joists must be braced laterally to prevent twisting and buckling, using horizontal rods fastened to the top and bottom chords of the joists or diagonal cross bracing.

The open-web joists are very quick to erect and easy to handle. Furthermore, they provide open spaces in the web that can be used to conceal MEP (McCormac & Csernak, 2012). They also offer the ability to accommodate a variety of geometric configurations that a typical steel beam cannot offer, shown in Figure 10. The open-web bar joists offer advantages that an I-beam cannot. Nevertheless there are disadvantages to open-web bar joists. For instance, they need to be pre-manufactured for the job, and may not offer the same strength as an I-beam. It is very important to weigh all options and their advantages/disadvantages when choosing the steel to support a floor system.

Figure 93: Geometric Configurations of Open-Web Bar Joists (Jenson & Moran, 2007)

2.5.3 Cast-in-Place vs. Precast Concrete

Cast-in-place concrete requires a great deal of labor because it takes a significant amount of time to erect the formwork. Furthermore, it requires a significant amount of steel reinforcement from ironworkers. On pour days the area is off limit to all other trades as the concrete must be properly installed and have appropriate time to cure. Cast-in-place concrete requires a great deal of manpower and demands proper scheduling.

Steel floor decking is one of the most common types of floor systems for cast-in-place concrete. The steel decking sits on the beams, and concrete fills the deck. The decking offers a high strength and an immediate working platform. The strength of the steel deck is relatively strong so the amount of concrete used can be reduced.

Prestressing forces are used to increase the bending, shear, and torsion capacities of precast concrete. The prestressing of the concrete prevents cracking from tensile forces by applying concentric or eccentric forces to the longitudinal direction of the structural element before any other loads are applied to the concrete (Nawy, 2009). This eliminates or greatly reduces the tensile stresses at the critical mid-span so that the sections can behave elastically. In turn, almost all of the concrete can be in its strength, compression.

Precast concrete is an extremely quick way of constructing floor systems, which requires minimal formwork (Nawy, 2009). An illustration of precast concrete planks is shown in Figure 11. Precast concrete is commonly used for roofs, but their popularity in floor use is growing. The prestressing of the concrete reduces deflections and the slab thickness usually by 65 to 80 percent. It also offers savings ranging from 65 to 80 percent of reinforcement. Unfortunately, the saving of materials is balanced by the high cost of materials and cost of prestressing the concrete. Precast concrete also requires more complex formwork, as the sections are usually composed of flanged sections with thin webs. The variation on the surface of the precast makes it necessary to cover with a 1 to 2 inches of mortar (McCormac & Csernak, 2012).

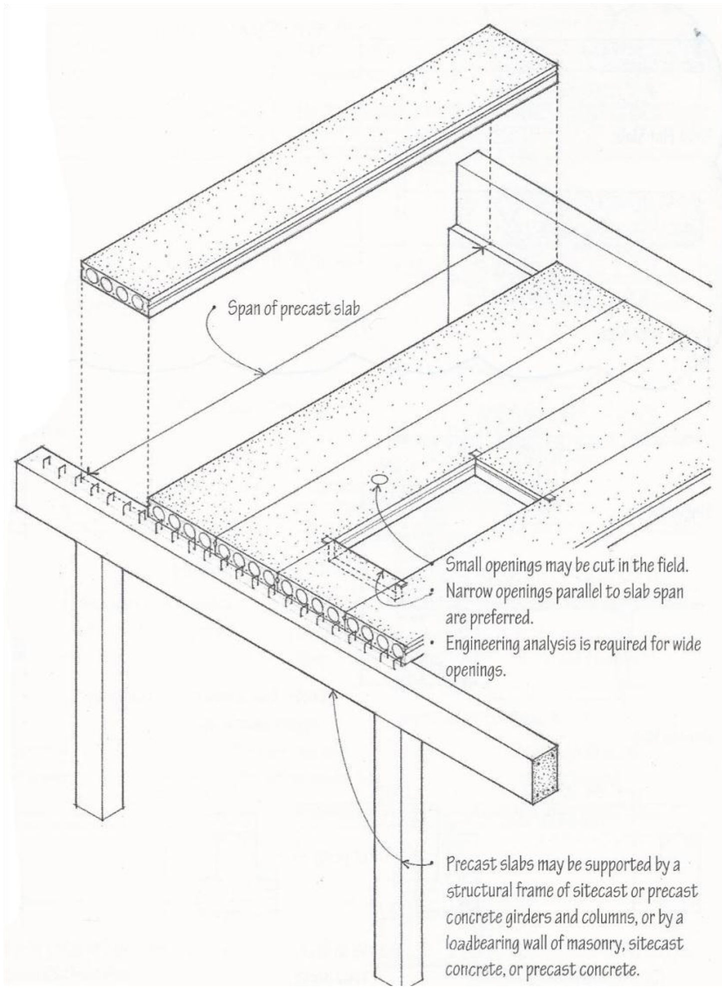


Figure 94: Precast Concrete Planks (Ching, 2008)

A difficulty when using precast concrete is that construction scheduling must be very accurate (Nawy, 2009). In order to coordinate the delivery and installation of the planks, proper lead times must be calculated. The use of precast units can offer some worthy advantages. Generally, the cost of construction difference between prestressed and reinforced concrete is not very large. The long-term savings of precast are substantial; some advantages include less maintenance required, a longer working life possible because of the quality control of the concrete, and a foundation experiencing far less force as the cumulative weight of the building is reduced.

2.5.4 Composite Construction

Composite construction utilizes shear transfer between the steel and the concrete to provide less deflection (Viest, Colaco, Furlong, Griffis, Leon & Willie, 1997). Formed steel deck is used for almost all composite building floors. The strength of the beam is increased, as the concrete serves as a cover plate to the upper flange of the beam. The composite floor system benefits the strength of the system as it makes use of the high compressive strength of concrete. This in-turn causes the steel to be in a greater amount of tension. The strength of both materials is utilized, which results in less steel required to provide adequate design. Composite construction allows the contractor to save money, as less material is needed. The design also can reduce the overall floor thickness required.

Composite construction is helpful when dealing with large loads and long beams (McCormac & Csernak, 2012). As previously mentioned, it can offer great savings and superior strength in design. A disadvantage of composite construction is the cost of the steel anchors and their installation can exceed the amount of savings of other materials. For this reason, it is not recommended to use composite construction for short spans and lightly loaded floor systems.

2.5.5 Expansion Joints

"Contrary to public perception…buildings move" (Arsenault, 2012).Vertical displacement, thermal displacement and seismic displacement are all possible building movements. Vertical displacement can occur due to different portions of a building having varying heights and sizes, and different types of foundation designs. When different foundations are a factor, the amounts of settlement may be inconsistent. Thermal displacement, also known as lateral shear, may occur because of wind or external building attachments. Last but not least, the severity of seismic displacement, which is considered the worst displacement because the building moves both vertically and horizontally, is based on the scale of an earthquake.

Construction forces are rare because construction is not an ongoing factor. Due to all of these displacements, almost all structures contain expansion joint systems. Most externally placed expansion joints are used on a small scale to make connections between smaller structural components, however it is not uncommon to see an expansion joint system that connects entire buildings, similar to the expansion joint system in St. Vincent Cancer Center. These larger expansion joint systems are referred to as building separation joints. When using a building separation joint, the overall intention is to separate a larger building into smaller discreet sections that will be able to act independently when dealing with displacement forces. “It is important to design a building with no critical structures spanning across the joint because the purpose of the joint will be lost” (Arsenault, 2012).

2.5.6 Building Information Modeling (BIM) in Structural Analysis

Using computer software to evaluate a structure is another extension of BIM. One of the key features of BIM is interoperability (Smith, 2009). This is when each firm uses the software most appropriate for its tasks, and the data is exported to another program or shared through coordinating software. Figure 12 below shows the graphical representation of interoperability in construction.

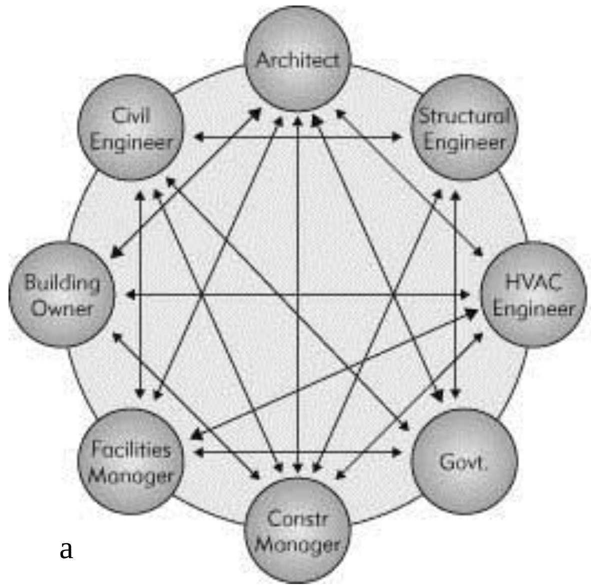


Figure 95: Interoperability (Smith, 2009)

Figure 12a shows that different parties coordinate with other certain parties to complete their task, through meetings, document exchange, and use of specific software. Figure 12b shows that all the data is compiled into one centralized database with interoperable electronic exchange, which can display each party's role in the final product. The final model will usually show discrepancies and items that need to be fixed, and each firm will change their part accordingly. The process repeats itself multiple times throughout a project to ensure the project is completed correctly and on time. Our project will test BIM interoperability through a combination of *Revit* and *Primavera* files integrated in *Navisworks* for the 5D model and structural analysis of *Revit* models with Autodesk *Robot*.

Autodesk *Robot* is a fairly new product, but is already gaining recognition for its application in structural analysis ("Autodesk Expands BIM," 2008). The software contains its own structure-building interface, or users can import *Revit* files and use the analytical design of the structure to complete various tests and simulations (Autodesk, 2010a). Figure 13 represents all the data that is combined to create the structural documents, including a 3D model, fabrication drawings, and other construction documentation.

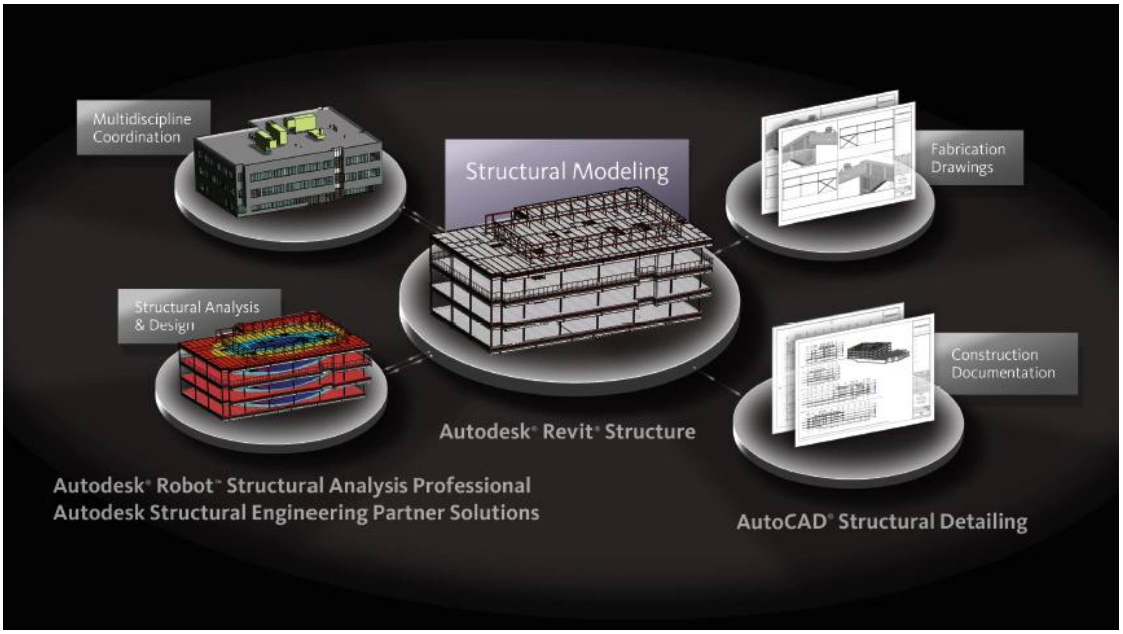


Figure 96: Structural Modeling (Autodesk 2010a)

Robot is another extension of BIM that builds on the goal of interoperability. It allows structural engineers to collaborate with the architect and other trades to improve process efficiency and minimize the potential for errors and omissions. The program allows engineers to analyze concrete and steel members in certain conditions and produces graphical and numerical results of each test. *Robot* considers real-world conditions and regulations; it is integrated with 40 steel codes, 30 concrete codes, and 70 design codes.

2.6 Building Codes

Building codes are a set of rules that establish a minimum level of quality and safety for all construction ("Public safety," 2012). They are intended to protect public health, safety and general welfare. Engineers and architects must follow the appropriate building code for the appropriate occupancy classification in the design of a building. The Board of Building Regulations and Standard (BBRS) administer the Massachusetts's building code. The 8th edition is the current publication of the building code, which uses a combination of codes from the

International Code Council (ICC) and separate amendments for Massachusetts. The code is altered often as new codes are adopted. On March 1, 2012 the BBRS will adopt the IECC 2012, which will take full effect after a full year.

The current building code is a compromised version of the International Building Code 2009 (IBC), which originates from the ICC. The IBC should be used in compliance with the Massachusetts Amendments to the IBC. The purpose of the IBC is to ensure safety of buildings by setting limits on design values for the structure design (IBC, 2009). In any case where the codes and regulations do not agree with each other, the most restrictive code should be used.

St. Vincent Hospital will have occupants that are receiving medical treatment, surgical processes, nursing, and are generally incapable of self-preservation so the building and design should comply to all codes and regulation of the IBC occupancy of 08.3 Group I-2 (IBC, 2009).

3.0 Methodology

Our project will explore two alternative structural designs for the St. Vincent Cancer Center. It will be necessary to analyze the proposed designs for structural stability, along with evaluations of cost and schedule. The goal is to investigate whether an alternative design can be identified that provides adequate design strength consistent with the current structure and offers savings in both cost and time. The first design will replace parts of the beam system with open-web bar joists. The second design will consider the application of precast concrete planks for the floor slabs instead of cast-in-place concrete on metal decking. Our process of evaluation will consist of *Revit* modeling, structural analysis, cost estimates, and schedule breakdowns. Following our evaluation, we will create a 5D model depicting our recommended structure coordinated with time and budget. Lastly, we will assess the importance of the expansion joint connecting the new building to the existing, adjacent parking garage.

3.1 3D Modeling and Structural Analysis

A large portion of the project relies on correctly and accurately designed *Revit* models. The models must be seamless in order to produce usable results when they are eventually exported to *Robot*. The design of structures is controlled by building codes and design specifications. We will design a new floor system and complete a structural analysis of the beams and joists that support the system. Also, we will make sure that this design satisfies both the building codes for the Massachusetts Building Code and the design requirements. To do so we will use *Robot* for the majority of the work. However, hand calculations will be completed to ensure the understanding of design and to verify the *Robot* calculations. After a benchmark is set with the current structural design, the two alternative models can be created off of the baseline. It will be important to think as an architect and structural engineer so that we pay attention to every detail and produce the best possible product.

3.1.1 Baseline Design (Benchmark)

Before building and analyzing models of our proposed designs, the team must investigate the current structure to use as a benchmark for analysis. A *Revit* model will be created using 2D structural drawings that were provided by Gilbane. St. Vincent Cancer Center consists of a concrete foundation and an open mezzanine area in the two-story first floor. The I-beam systems on the second and third floors are rather similar with bays of 32'x30'. The beams for the second are W16x26 and on the third are W16x24. The interior girders of both floors are W24x62. Both floors' beam systems support a concrete slab on steel decking. We will use the loads of these floors to assist us with calculations necessary in determining alternative designs. The current design drawings will be used to create a 3D model of the foundation, columns, beams, girders, decks, and concrete slabs. It will also be important to keep elements grouped in particular families in order to keep track of the many items in the model. Once the model is complete, it can be exported to *Robot* for structural analysis, and the proposed structural design models can be created from the baseline model.

A *Robot* analysis will provide the team with results reflecting the effects of the design loads. If designed according to the structural drawings, the calculations should produce favorable results because the architect and structural engineer have most likely already completed a structural analysis of the building. The *Robot* structural analysis of the baseline design will be studied to ensure that the *Robot* software has interpreted the *Revit* model correctly. Also, this will aid in our understanding and develop our skills with *Robot.* To study and comprehend the software, we plan to compare the *Robot* calculations with the methods of hand calculations and to identify where to find the necessary information and calculation results in *Robot.*

3.1.2 Proposed Open-Web Bar Joist Design

Our proposed designs will use the current design as a starting point, and then it will implement open-web bar joists to that system. The design will replace the I-beams supporting the concrete slab with open-web bar joists. The current design of rolled beam sections along the column lines will remain the same in this design to maintain the stable skeleton of the structure. Further, we will examine alternative methods of bay design for the open-web bar joists, delving into several different schemes and spacing of the joists. The *Revit* process will be expedited because we can duplicate the baseline model and change only the elements that we are examining. Therefore, columns and foundation will not change from the baseline model, which will keep the *Robot* data focused on the differences between the open-web bar joist and existing I-beam framing. This will help us to make comparisons between the existing I-beams and open web bar joists. To do so we will determine the specific open-web bar joists that meet design criteria. They will then be compared to the baseline design with cost, schedule, and constructability.

We plan on completing a structural analysis of the open-web bar joists with the same loads on the floor system that were used for the baseline model. Once exported to *Robot*, we can calculate the moments, forces, and displacements. Examination of this data, the baseline data, and industry data should allow the team to determine the most effective bar joist design. The bar joists will offer various advantages and disadvantages, which will be evident in our cost and schedule breakdowns.

3.1.3 Proposed Precast Concrete Slab Design

The second alternative design will investigate the use of precast concrete planks instead of cast-in-place concrete for the elevated slabs. The two different slabs are popular options for supporting and resisting various loads in the skeleton of steel framed buildings. The precast planks will be important elements to create the floor slabs in this *Revit* model, and the team will have to ensure proper layout and thicknesses. A well-designed structure will improve the interoperability of the model, so that *Robot* can yield accurate results with less chance for error.

By designing the new floor system we plan on reducing the weight of the floor, while maintaining adequate design in supporting the loads. We hope to find benefits in the precast floor system and make comparisons with the cast-in-place on steel deck concrete of the baseline design. The type of precast concrete planks will be determined to best fit the floor system and meet the loads present in the floor system. Our design will have a thin top layer of concrete with steel mesh reinforcement over the planks to create a single, composite slab. This will also benefit our *Robot* analysis because there will be less chance for error in the software, and it will provide us with more refined results. We will use *Robot* and hand calculations to help us design a precast system that will meet all of the design specifications. We will then verify the structural integrity with a *Robot* analysis. The cost estimate and schedule will also be affected by the size and layout of the planks and top layer of cast-in-place concrete.

3.2 Cost and Schedule

Two important factors that can influence a project are cost and schedule. The owner must have appropriate funds to finance the project, and the schedule of the project is needed to finish the project in an appropriate time span. With a new floor system, both of these factors can be greatly impacted. The first calculation that must be done to find a baseline for analysis is to compile the steel and concrete subcontractor bids. With this, we can determine the cost of the steel and concrete being used in the current design. From this we can get a cost per ton of these materials which will give us a unit cost to determine the price of the alternative designs. In order to determine the effects on scheduling we must take a look into Gilbane's *Primavera* file to establish the fabrication lead time of the floor system. Using this information, we can calculate the time needed to install either the open-web bar joists or pre-cast concrete. A shortened schedule or a new critical path can help to speed up the project and get the owner into the building faster. In the case of open-web bar joists if there is less material needed, then there will be savings on installation and delivery time. With pre-cast concrete, the project can be sped up because there is no wait for the concrete to set, although the pre-cast must be pre-ordered which may delay the schedule. Construction traffic will be reduced without the need for concrete trucks to pour each slab. A setback however is that cranes will be needed to set the precast slabs, which may increase the amount of traffic. These can decrease the length of the job which could then in turn produce savings on the project. With a shorter schedule, loans can be paid off sooner, which will eliminate interest payments. Overall the alternative that produces cost and time savings could prove to be an effective option for the project.

3.3 Evaluation of Alternatives

In order to recommend the most effective alternative design, we plan to evaluate all the components that are mentioned above. Following the design of the structures in *Revit*, we will use both hand calculations and *Robot* to ensure that our alternatives are structurally sound. We will use the same design loads that the structural engineers and architects used for the current design. Once our models can sufficiently support all the loads required, we can begin pricing all the elements in each design. This will include a cost-estimate for the baseline model, so that we may see any cost-savings that the alternative designs may offer in materials, delivery, or labor.

Once the budget for each structure is set, we will move on to creating a schedule for each model. In order to create as accurate a time-line as possible, we will be looking at lead times for the materials and the man-hours for installing each system. Again, the baseline schedule will be used to determine if there are any ways to decrease completion time. After the three analyses, structure, cost, and time, we will define our recommended design. The selected alternative should be able to support the required design loads and offer cost- and time-savings. Our recommendation will be based on the model that comes closest to the optimal alternative.

3.4 5D Model

To make the assessments and reach our recommendations, we will go through three main analyses. First, we will create a 3D *Revit* model for each case and use *Robot* to structurally evaluate each structure. Next, we will consider the amount of materials and labor that varies with each model and assign costs to different items. Using this information based on material quantities and industry data, we will create cost estimates for each design, which will breakdown the costs and show advantages and disadvantages for each system. Lastly, we will use *Primavera* to create a schedule for each design and see which designs can be most time-effective. These three components can be combined to create a 5D Model, which helps to visualize the timeline that is expected for both cost and construction.

Based on the results of our evaluations, the 5D model will be created for our recommended alternative design. We plan to use *Navisworks* to coordinate the *Revit* model with the cost estimate and *Primavera* schedule. The model will simulate the duration of our recommended design as structural steel is erected and concrete slabs are constructed. As these activities are displayed in a 3D simulation, the total cost of the design will increase corresponding to the completed construction. This will be a useful tool to visually represent our proposed design and the logistics associated with it.

3.5 Building Separation Joints

Building separation joints are commonly used throughout commercial construction. Currently, the Cancer Center is being constructed within feet of an existing parking garage. The two structures will need to be joined by a building separation joint because of the close proximity; making it another variable that we will have to account for in our structural analysis. We will compare our alternative floor systems structural calculations with the current design to confirm that these designs will satisfy the building separation joint requirements. In addition to this, we will also address any Massachusetts building codes that may affect construction with the addition of the building separation joint. We also plan to examine case studies of modern construction to determine the most common types of displacement that may occur in the Worcester area. We hypothesize that shear displacement may occur to the parking garage because the Cancer Center consists of a below grade level. The construction of this level requires removing soil from around the foundation of the parking garage which is a factor in shear displacement. Vertical displacement may occur due to the Cancer Center settling over time. It is important to determine the impact of these displacements to ensure that our alternative designs will be effective.

4.0 Deliverables

Over the course of the next two terms we plan to complete all of our methods and arrive at an economically feasible and structurally sound alternative design of the floor system. Throughout the project we will be creating various deliverables that will assist us in finding an effective floor system to be used in the St. Vincent Cancer Center. We will build three separate *Revit* models to represent each floor system design. These will then be analyzed through *Robot* and hand calculations to determine the forces, moments and displacements caused by design loads in the structure. Cost estimates for each floor system will be calculated to represent the costs of material, labor, and delivery. A schedule for each system will then be established to determine time savings that each design can offer. A 5D model will then be produced in *Navisworks* to assist in the visualization and simulation of our recommended design. An exploration of building separation joints will then be used to create a set of calculations that can be compared to current design of the building. A work plan for our project can be seen in Appendix A.

5.0 Conclusion

During this project, we expect to examine many aspects of the construction process regarding St. Vincent Cancer Center. Construction of this facility will be taking place in the new City Square development located in Worcester, Massachusetts. We will compare two alternative structural designs with the current building structure, including cost estimates and schedules. The cost and scheduling analysis will be completed to determine the most effective alternative floor system design. We will also use Building Information Modeling (BIM) to assist in this process and to display a 5D model of our recommended design. The recommended design will need to work with the building separation joint, or another suitable joint must be determined. This proposal will be used as a guide to eventually present an alternative design to St. Vincent Hospital for their Cancer Center.

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Appendix B: Subcontractor and Engineer List

Table 4. Subcontractor and Engineer List

Architect (including Structural Engineer, Civil Engineer, Landscape Architect, and BIM Specialist)	Symmes, Maini, & McKee Associates – Cambridge, MA
Consulting Engineers (including Mechanical, Electrical, Plumbing, and BIM Coordinator)	Thompson Consultants – Marion, MA
Geotechnical Engineers	McPhail Associates – Cambridge, MA
City Square Site Engineers	Nitsch Engineering – Boston, MA
Surveyors	Coneco Engineers – Bridgewater, MA
Sitework	Marois Brothers – Worcester, MA
Concrete	JL Marshall & Sons – Pawtucket, RI
Masonry	Empire Masonry – Walpole, MA
Structural Steel and Misc. Metals	United Steel – East Hartford, CT
Millwork	Iaccarino & Sons – Boylston, MA
Roofing	Silktown Roofing – South Grafton, MA
Waterproofing	Heritage Restoration – Rockland, MA
Doors, Frames, and Hardware	Columbus Door Company – Warwick, RI
Glass and Glazing	Massey's Plate Glass & Aluminum – Branford, CT
Ceilings	Central Ceilings – South Easton, MA
Flooring	Regal Floor Covering – Fall River, MA
Painting	ML McDonald – Watertown, MA
Radiation Doors and Shielding	Nelco – Burlington, MA
Elevators	Otis Elevators – Smithfield, RI
Plumbing	Harold Brothers Mechanical Contractors – Norwell, MA
HVAC	William F. Lynch Co. – Worcester, MA
Fire Protection	Arden Engineering Constructors – Pawtucket, RI
Electrical	Wayne J. Griffin Electric – Holliston, MA

Appendix C: Structural Column and Footing Schedules

FOOTING SCHEDULE (4000 PSF ALLOWABLE BEARING)				
Mark	Length	Width	Thickness	Reinforcement
F5	5' - 0"	5' - 0"	16"	5-#5 BOT, E.W.
F8	8' - 0"	8' - 0"	24"	10-#6 BOT, E.W.
F9	9' - 0"	9' - 0"	26"	9-#7 BOT, E.W.
F10	10' - 0"	10' - 0"	26"	10-#7 BOT, E.W.
F11	11' - 0"	11' - 0"	28"	9-#8 BOT, E.W.
F20	20'-0"	10' - 0"	36"	24-#8 BOT, L.W. 28-#8 BOT, S.W.

NOTES:

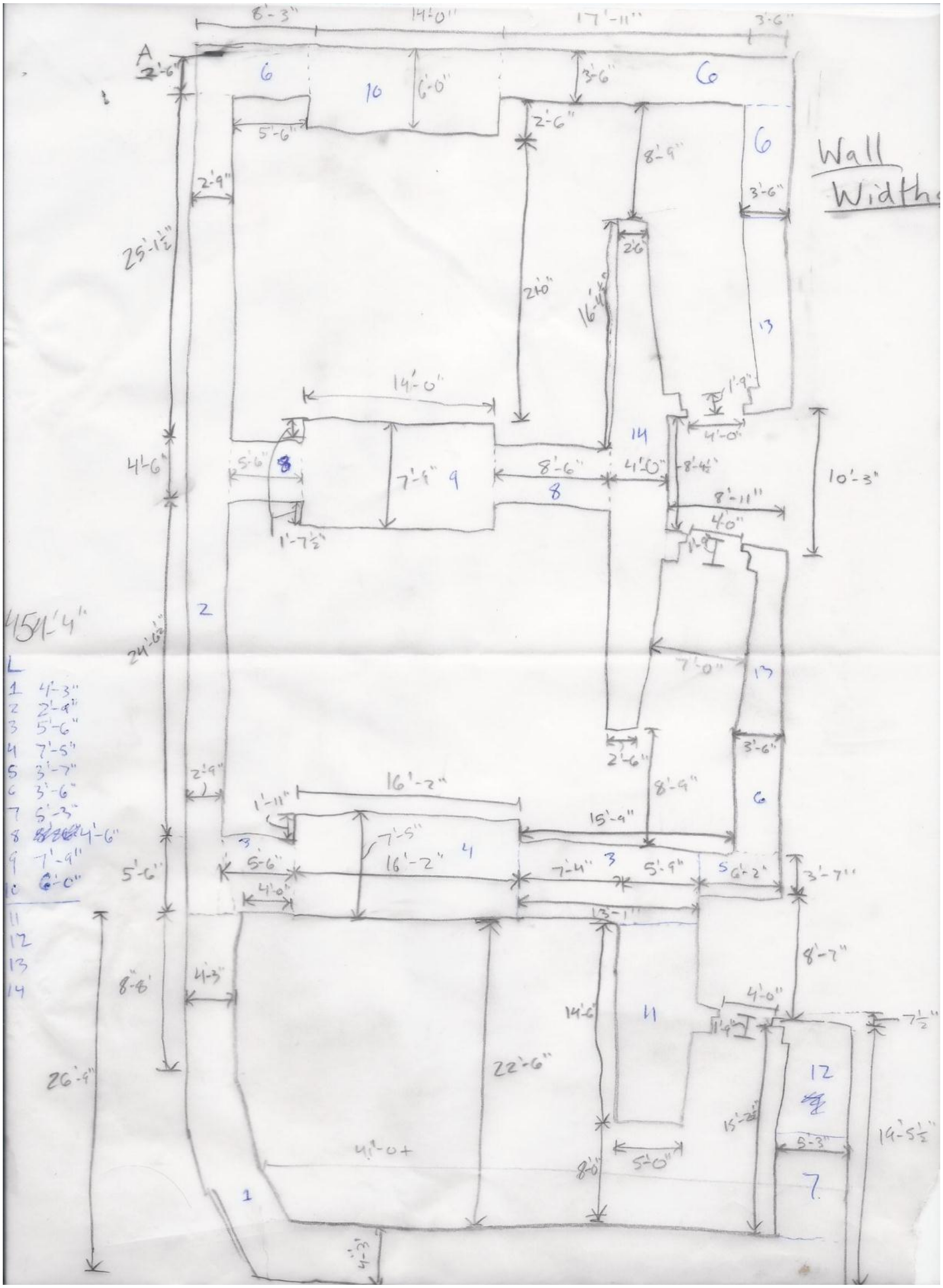
1. PROVIDE AN ADDITIONAL LAYER OF TOP REINFORCING TO MATCH BOTTOM REINFORCING AT FOOTING DESIGNATIONS FOLLOWED BY THE SUFFIX "a".

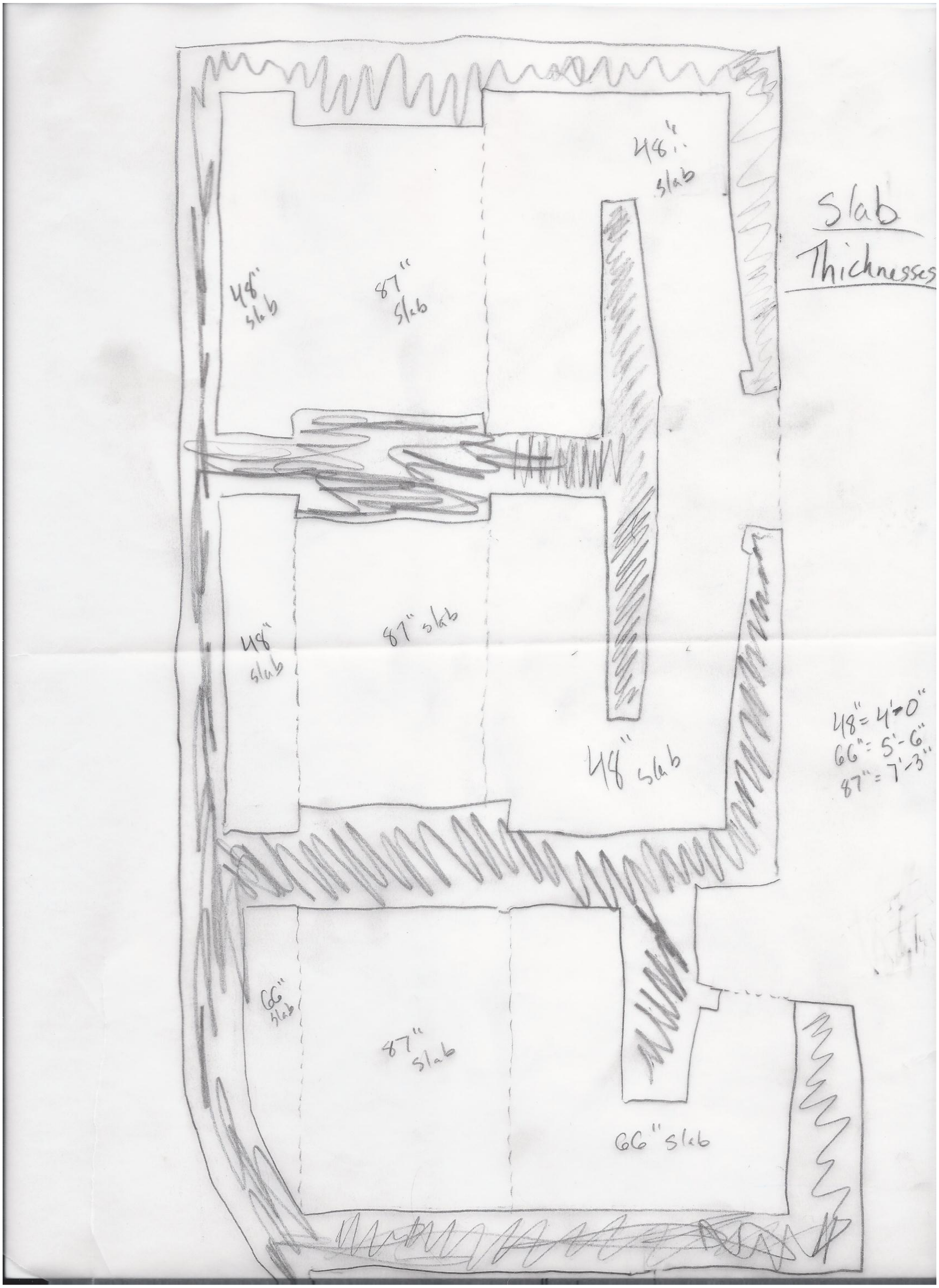
2. THICKEN FOOTINGS AT ANCHOR BOLT LOCATIONS IF REQ'D. TO PROVIDE A MINIMUM 3" BOTTOM COVER.

STRUCTURAL COLUMN SCHEDULE				
Mark	Size	Base Plate (TxBxN)	Anchor Bolts	Detail
C1	W12X40	1"X20"X1'-8"	4- 3/4" DIA.X12"	A
C2	W12X87	2 1/4"X22"X1'-10"	8-1 1/2" DIA.X24"	B
C3	W12X96	2 1/4"X22"X1'-10"	8-1 1/2" DIA.X24"	B
C4	W12X106	2 1/2"X24"X2'-0"	10-1 1/2" DIA.X24"	C
C5	W12X120	2 1/2"X24"X2'-0"	10-1 1/2" DIA.X24"	C
C6	HSS5X5X5/16	See Note 6		
C7	HSS4X4X5/16	See Note 6		

NOTES:
1. ANCHOR BOLTS ARE ASTM F1554 HEADED BOLTS U.O.N.
2. SCHEDULED ANCHOR BOLT LENGTH EQUALS THE EMBEDMENT LENGTH, AND THE STANDARD PROJECTION ABOVE CONCRETE IS 4-1/2" MIN. FOR ALL BASE PLATES 1-1/2" AND LESS IN THICKNESS, 6" FOR ALL BASE PLATES BETWEEN 1-1/2" AND 3" THICK.
3. ALL COLUMNS CONTINUOUS FOUNDATION TO ROOF LEVEL UNLESS OTHERWISE NOTED.
4. PROVIDE 1/4" LEVELING PLATE SAME SIZE AS BASE PLATE.
5. AT BRACED FRAME AND MOMENT FRAME COLUMNS PROVIDE PLATE 3/8"X3 3/4"X3 3/4", WASHER WITH 1/16" OVERSIZED HOLE FOR ANCHOR BOLT. WELD TO BASE PLATE WITH 1/4" FILLET WELD ALL AROUND.
6. POSTS BEARING ON STEEL SHALL HAVE A MINIMUM 3/4" BASE PLATE AND (4)-3/4" DIA. A325 BOLTS.

Appendix D: Design Drawings for Radiation Vault




Slab Thicknesses
48" slab
48" slab
87" slab
48" slab
87" slab
48" slab
48"=4'-0"
66"=5'-6"
87"=7'-3"
66" slab
87" slab
66" slab

Appendix E: Design Loads

Design Loads

Loads: Provided by Gilbane, 50.01

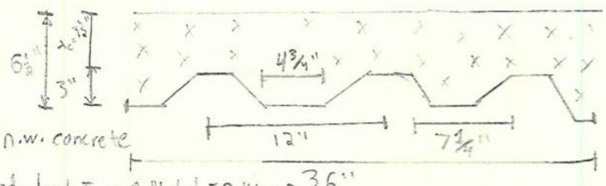
Dead Load: (Vulcraft catalog pg. 54)

Normal weight concrete = 145 PCF

Total slab depth = 6.5"

Dead Load = 63 psf

* Use for all 20 gage steel & $3\frac{1}{2}$" n.w. concrete



Roof Dead Load = $1\frac{1}{2}$" 20 gage galvanized steel Type B Metal = 2.14 psf
OR = $1\frac{1}{2}$" 18 gage galvanized steel Type B Metal = 2.82 psf
OR = 63 psf where deck and concrete are used

Live Loads:

Ground Floor on Slab on Grade:	250 PSF
Vault Slabs Subject to automobile:	250 PSF
Office Areas:	100 PSF
Mezzanine and Stairs:	100 PSF
Mechanical Penthouse:	150 PSF

Snow Load

$P_g = 55$ PSF, $C_e = 1.0$, $I = 1.0$, $C_t = 1.0$

$P_f = 0.7\, C_e C_t I P_g$

$P_f = 0.7(1)(1)(1)(55\text{ psf})$

$P_f = 38.5$ psf

Wind: IBC 1609.2

$P_{net} = q_s K_z C_{net}$

$q_s = 0.00256\, V^2$, $K_{zt} = 1.0$, $V = 100$ mph, $I = 1.0$

Seismic:

$V = C_s W = S_{DS} W / (R/I)$

$S_S = 0.24$, $S_1 = 0.067$, $F_a = 1.61$, $F_v = 2.40$

$S_{MS} = F_a S_S = 0.386$

$S_{DS} = \frac{2}{3} S_{MS} = 0.257$

$I = 1.0$, $R = 3.00$

Base Shear: $V = 435$ kips

Loads on Floor 3: (OFFICE AREAS) 30'x 32' Bays (Also mezzanine & stairs)

Dead Load:

(ASD Combinations) IBC section 1605.3.1

$D+F = 63\,psf$

$D+H+F+L+T = 63\,psf + 100\,psf = \boxed{163\,psf}$

$D+H+F+(L_r \text{ or } S \text{ or } R) = 63\,psf$

$D+H+F+0.75(L+T)+0.75(L_r \text{ or } S \text{ or } R) = 63\,psf + 0.75(100\,psf) = 138\,psf$

$D+H+F+(W \text{ or } 0.7E) = 63\,psf$

$D+H+F+0.75(W \text{ or } 0.7E)+0.75L+0.75(L_r \text{ or } S \text{ or } R) = 63\,psf + 0.75(100\,psf)$
$= 138\,psf$

$0.6D+W+H = 0.6(63) = 37.8\,psf$

$0.6D+0.7E+H = 37.8\,psf$

Design Criteria:

$D = 517.2\,psf$

$E = 0$

$F = 0$

L: Varies => Office = 100 psf

$L_r = 0$

$S = 38.5\,psf$ on Roof => 0 other floors

$W_{max} = 0$ (Neglected for floors)

$H = 0$

T: self straining Load = 0

R: nominal load due to rainwater or ice = 0

Roof Loads:

$D = 2.14\ psf, 2.82\ psf$, or $63\ psf$ (Varies)

$LL = S = 38.5\ psf = p_f$

ASD Load Combinations: (IBC section 1605.3.1)

$D + F = 2.14, 2.82$, or $63\ psf$

$D + H + F + L + T = 2.14, 2.82$, or $63\ psf$

$D + H + F + (S) = \underline{40.64, 41.32, \text{ or } 101.5\ psf}$ ← Use this Load Combination

$D + H + F + 0.75(L+T) + 0.75(S) = 31.02, 31.695$, or $91.875\ psf$

$D + H + F + (W \text{ or } 0.7E) = 2.14, 2.82$, or $63\ psf$

$D + H + F + 0.75(W \text{ or } 0.7E) + 0.75L + 0.75(S) = 31.02, 31.7$, or $91.88\ psf$

$0.6D + W + H = 2.14, 2.82$, or $63\ psf$

$0.6D + 0.7E + H = 1.29, 1.7$, or $37.8\ psf$

$\frac{h_c}{h_b} > 0.2 \Rightarrow$ Snow drift Required

Drift Load: Maximum intensity

$\gamma = 0.13\,p_g + 14 = 0.13(55\ psf) + 14 = 21.15\ pcf$ = Unit weight of Snow

$h_b = \frac{p_f}{\gamma} = \frac{38.5\ psf}{21.15\ pcf} = 1.82$ feet (1'10")

$h_c = [h_b - \text{height difference between Roofs}] = 1.82 \text{ feet} - 8'10" = -7"$

Raised Area = 103' x 38'10" (three sides)

$\frac{h_c}{h_b} > 0.2$ Snow drift Required

Leeward:

$l_u = 103'$

$h_d = 0.43\sqrt[3]{l_u}\sqrt[4]{p_g+10} - 1.5 = 0.43\sqrt[3]{103}\sqrt[4]{55+10} - 1.5 = 4.22$ feet

$p_d = h_d\,\gamma = 4.22 \text{ feet}\,(21.15\ pcf) = 89.25\ psf$

$p_{total} = p_d + p_f = 89.25\ psf + 38.5\ psf = 127.75\ psf$

ASD Load Combination: (worst case)

Loads:

$D + H + F + (S) = 2.14, 2.82$, or $63\ psf + 127.75\ psf = 129.89, 130.57$, or $190.75\ psf$

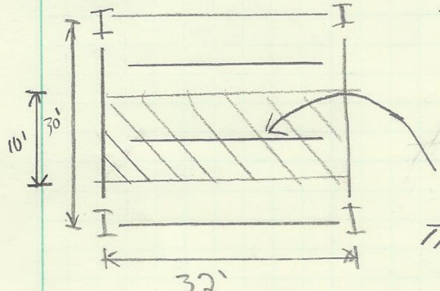
Width of drift: $W = 4\,h_d = 4(4.22 \text{ feet}) = 16.88$ feet

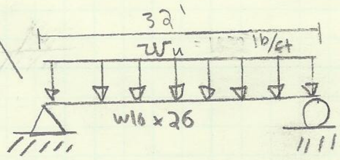
Appendix F: Baseline Model Structural Hand Calculations

Baseline Moment 1

Maximum bending moment:

Floor 2: 32'x30' Floor





Found Load combination on Previous Page

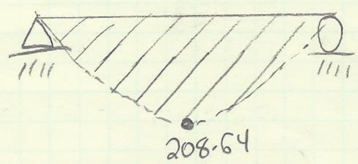
$D+H+F+L+T = 63psf + 100psf = 163psf$

$163psf\,(10ft) = 1630\,PLF$

$W_u = 1630\,plf$ (without Beam Weight)

$W_u = 1.630\,k\text{-}ft$

Max moment $\Rightarrow M = \frac{wl^2}{8} = \frac{1.630\,kips/ft \times 32ft^2}{8} = 208.64\,k\cdot ft$

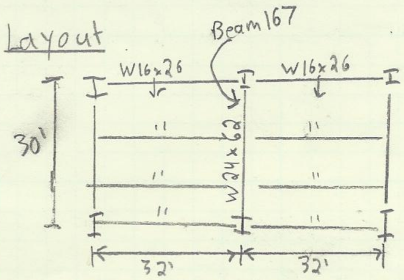


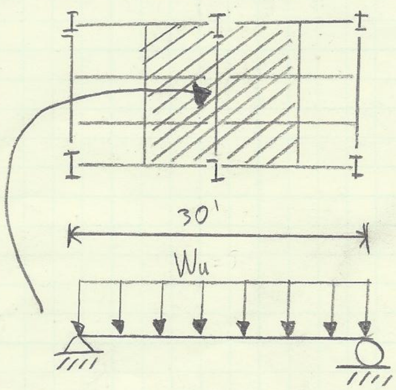
M (kips-ft)

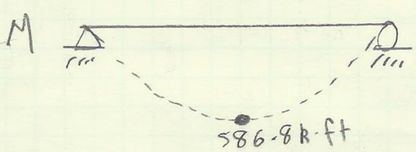
Find Maximum Moment in Beam 167:

FLOOR 3: 32' x 30' Bay

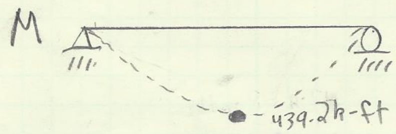
Layout



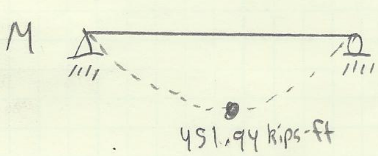




With Live Load Reduction



With LL Reduction & Beam Weight



ASD

Load Combination: (Found on Appendix E:)

D = 63 psf   L = 100 psf for office Areas

D + L = Greatest Load

Tributary Area:

$A_T = 32' \times 30' = 960$ sq.ft.

Dead Load = 63 psf (32 ft) = 2016 plf

Live Load = 100 psf (32 ft) = 3200 plf

$W_u = D + L = 2016\text{ plf} + 3200\text{ plf}$

$W_u = 5216\text{ plf} = 5.216\text{ k/ft}$ (doesn't include Beam weights)

$$M_{max} = \frac{W_u L^2}{8} = \frac{5.216\ \text{k/ft} * (30^2)}{8}$$

$M_{Max} = 586.8$ k·ft

Live Load Reduction $A_t > 400$ sq.ft

Influence Area $= A_I = 2A_t = 2(960\text{ sq.ft})$

$A_I = 1920$ sq ft

Live load Reduction:

$0.25 + [15/\sqrt{A_I}] = 0.25 + [15/\sqrt{1920}]$

LL Reduction = 0.59

Live Load = 100 psf (32 ft)(0.59) = 1888

$W_u = D + L = 2016 + 1888 = 3904\text{ plf} = 3.904$ kip ft

$$M_{max} = \frac{3.904\ \text{kip ft}\ (30^2)}{8} = 439.2\ \text{kip ft}$$

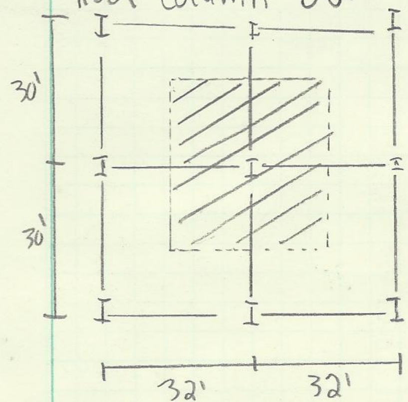
Dead Load with Beam Weight:

$2016\text{ plf} + 24\frac{\text{lbs}}{\text{ft}}\frac{(64\text{ ft})}{30'} + 62\frac{\text{lbs}}{\text{ft}} = 2129.2\frac{\text{lbs}}{\text{ft}}$

$$M_{MAx} = \frac{(2.1292 + 1.888)(30^2)}{8} = \frac{(4.0172\ \text{kip ft})(30^2)}{8} = 451.94\ \text{kip}\cdot\text{ft}$$

Force in Column:

Roof Column D6:



TRIBUTARY AREA:

$A_T = 32' \times 30' = 960\ ft^2$

Roof Design Loads:

$D = 2.14\ psf \quad S = 127.75\ psf$

$D: 2.14\ psf\ (960\ sq.ft) = 2054.4\ lbs$

$S: 127.75\ psf\ (960\ sq.ft) = 122{,}640\ lbs$

$W_u = D + S = 2.0544\ kips + 122.640\ kips$

$W_u = 124.70\ kips$

Required Axial force = 124.70 kips

With Live Load Reduction

Influence Area:

$A_I = 4A_T = 3840\ sqft$

Live Load Reduction:

$$0.25 + \frac{15}{\sqrt{A_I}} = 0.25 + \frac{15}{\sqrt{3840}} = 0.49$$

New Snow Load:

$S = 127.75(960)(0.49206)$

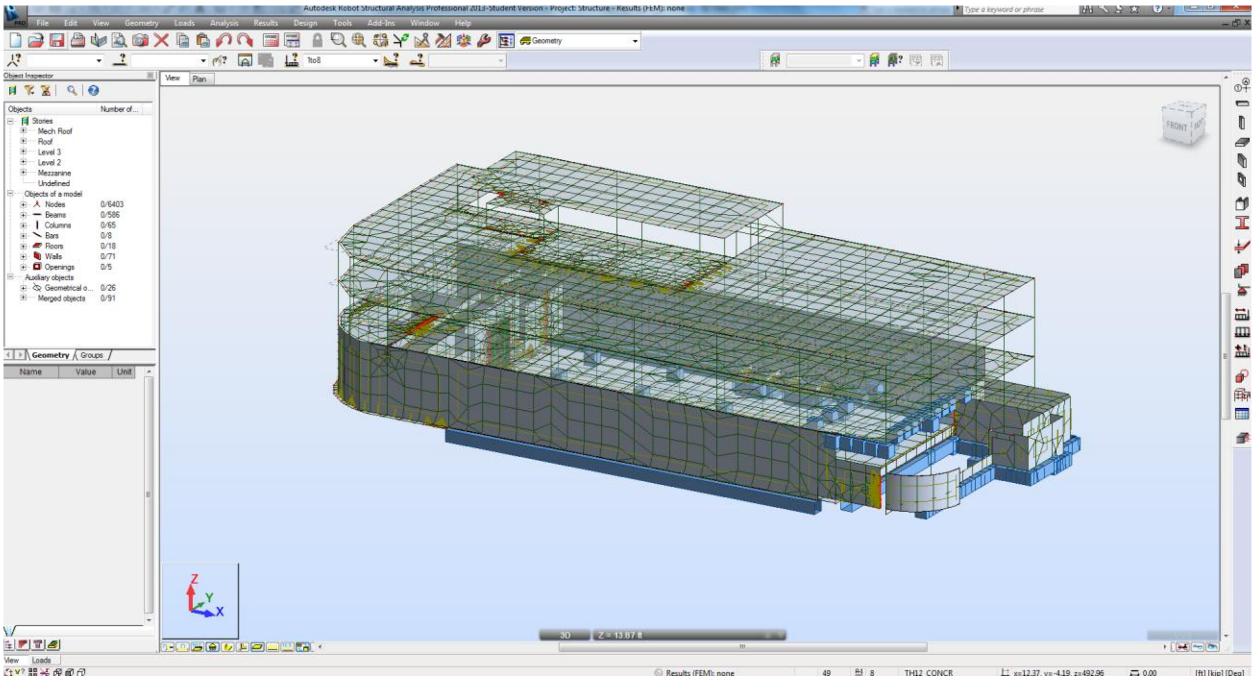
$S = 60.346\ kips$

$D + S = 60.348\ kips$

With Reduction $W_u = 60.35\ kips$

Appendix G: Guide for Factoring Loads in Autodesk Robot

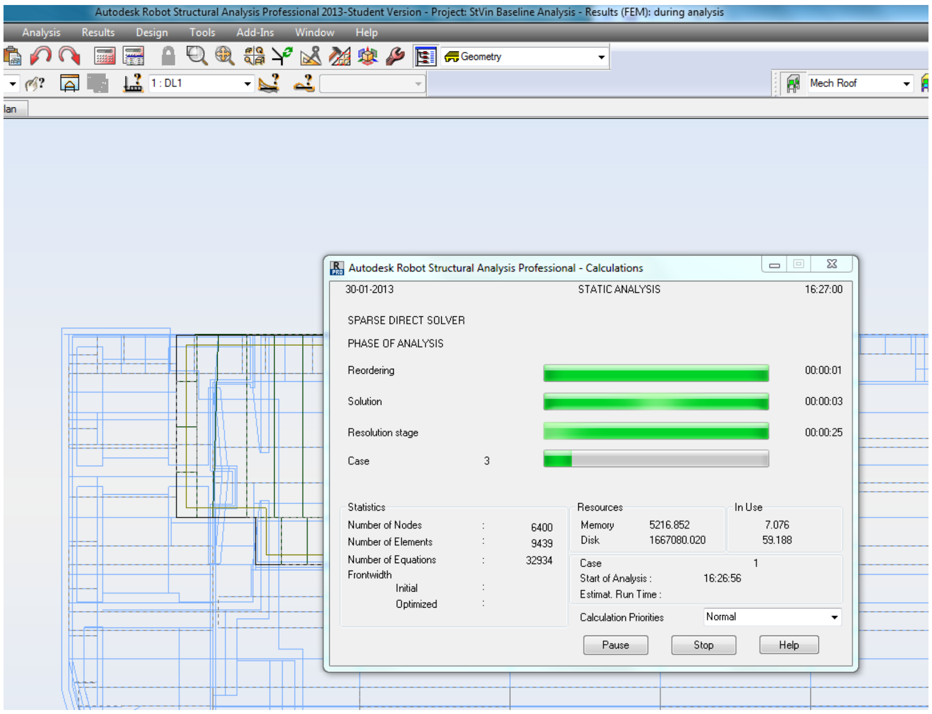
1. Once the *Revit* model is imported, the model should resemble a wire-framed structure based off the analytical model, seen below.



2. To check that the design loads transferred correctly, go to **Loads>Load Table** to arrive at the screen below. The table separates the loads by case and shows the magnitude of the force in the downward z-direction.

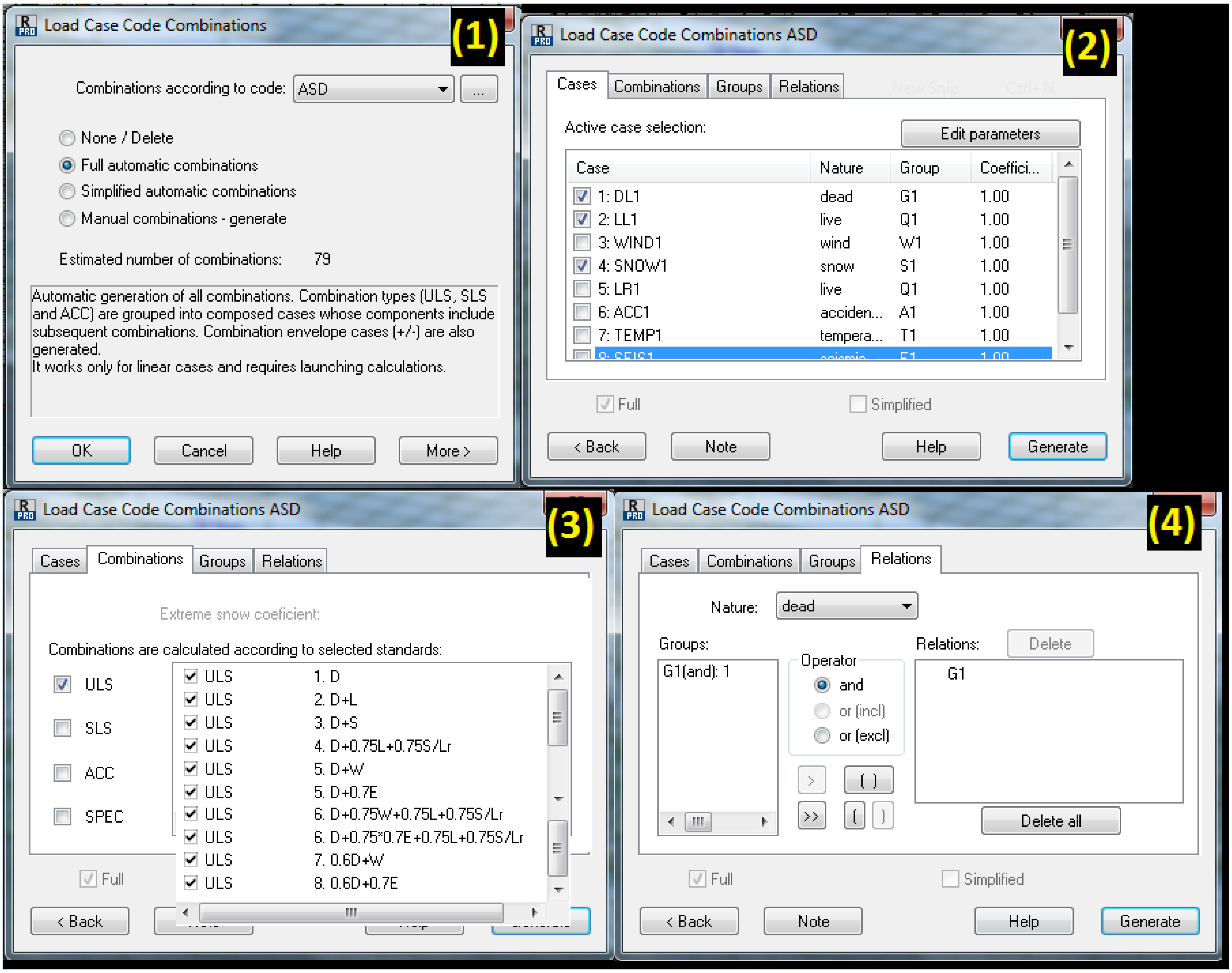
Case	Load type	List								
1:DL1	(FE) uniform	852	PX=0.0	PY=0.0	PZ=-0.00	global	not project.	absolute	Limits	MEMO:
1:DL1	(FE) uniform	850	PX=0.0	PY=0.0	PZ=-0.00	global	not project.	absolute	Limits	MEMO:
1:DL1	(FE) uniform	851	PX=0.0	PY=0.0	PZ=-0.06	global	not project.	absolute	Limits	MEMO:
1:DL1	(FE) uniform	842	PX=0.0	PY=0.0	PZ=-0.06	global	not project.	absolute	Limits	MEMO:
1:DL1	(FE) uniform	843	PX=0.0	PY=0.0	PZ=-0.06	global	not project.	absolute	Limits	MEMO:
1:DL1	(FE) uniform	846	PX=0.0	PY=0.0	PZ=-0.06	global	not project.	absolute	Limits	MEMO:
1:DL1	(FE) uniform	849	PX=0.0	PY=0.0	PZ=-0.06	global	not project.	absolute	Limits	MEMO:
1:DL1	(FE) uniform	856	PX=0.0	PY=0.0	PZ=-0.06	global	not project.	absolute	Limits	MEMO:
2:LL1	(FE) uniform	849	PX=0.0	PY=0.0	PZ=-0.10	global	not project.	absolute	Limits	MEMO:
2:LL1	(FE) uniform	856	PX=0.0	PY=0.0	PZ=-0.15	global	not project.	absolute	Limits	MEMO:
2:LL1	(FE) uniform	842	PX=0.0	PY=0.0	PZ=-0.25	global	not project.	absolute	Limits	MEMO:
2:LL1	(FE) uniform	843	PX=0.0	PY=0.0	PZ=-0.10	global	not project.	absolute	Limits	MEMO:
2:LL1	(FE) uniform	846	PX=0.0	PY=0.0	PZ=-0.10	global	not project.	absolute	Limits	MEMO:
2:LL1	(FE) uniform	841	PX=0.0	PY=0.0	PZ=-0.10	global	not project.	absolute	Limits	MEMO:
4:SNOW1	(FE) uniform	850	PX=0.0	PY=0.0	PZ=-0.13	global	not project.	absolute	Limits	MEMO:
4:SNOW1	(FE) uniform	852	PX=0.0	PY=0.0	PZ=-0.04	global	not project.	absolute	Limits	MEMO:
4:SNOW1	(FE) uniform	851	PX=0.0	PY=0.0	PZ=-0.13	global	not project.	absolute	Limits	MEMO:

3. Once the loads are confirmed, go to **Analysis>Calculations** to start calculations. Let the analysis run (below). Once calculations are done, load maps can be examined through cases. In order to show the loads factored, the group created cases that factored the loads using the **Automatic Combination** tool in *Robot*.

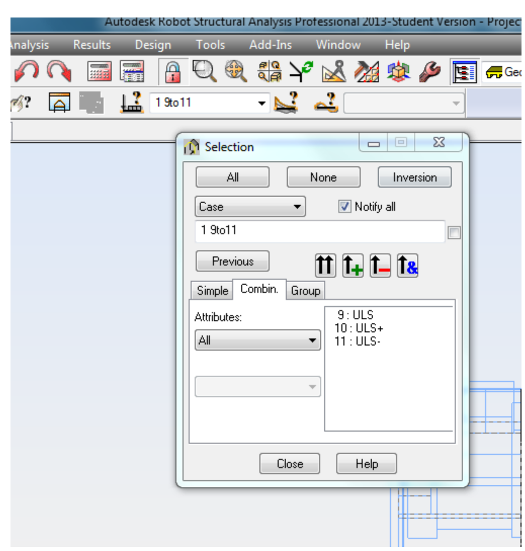


4. To represent the factoring of the loads, use the **Load>Automatic Combination** function. This opens up a dialog box (below, 1) which enables users to create case combinations. **Full automatic combinations** generates all combinations using ASD code and ULS standards. In the **Cases** tab (below, 2), the St Vincent analysis only needed dead load (DL1), live load (LL1), and snow load (SNOW1). The settings in the **Combinations** tab (below, 3) do not need to be changed; the default combinations use ULS standards which are sufficient for the analysis. Lastly, the user must add any groups that are to be considered in the **Relations** tab (below, 4); the St. Vincent analysis included G1 under

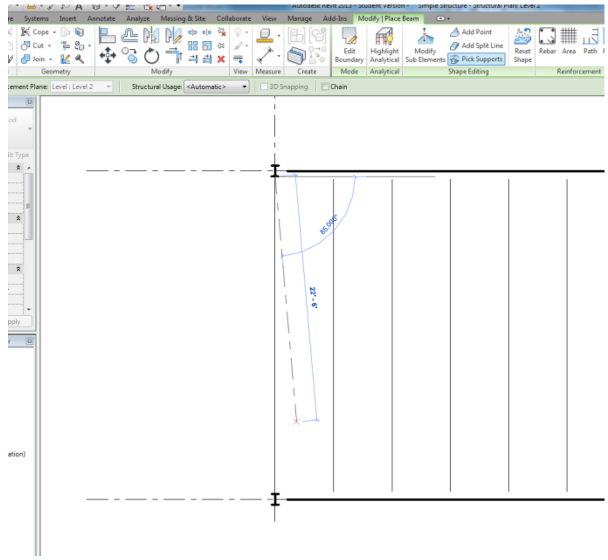
dead loads, Q1 under live, and S1 under snow. Once the settings have been set for the case combination, hit **Generate**, and three cases are created: ULS, ULS+, and ULS-



5. ULS is a case that takes the average of each calculation, while ULS+ and ULS- look at the maximum and the minimum, respectively. In the **Loads>Select Cases** box (or case drop down box), cases 9, 10, and 11 are the three ULS cases (right). Select which case is needed for analysis and refresh MYY moment maps.

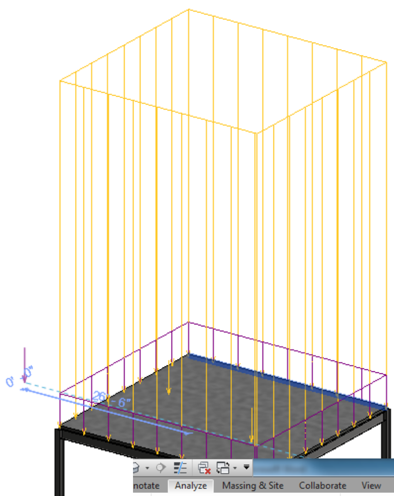


Appendix H: Guide to Export 3D Model from Revit to Robot

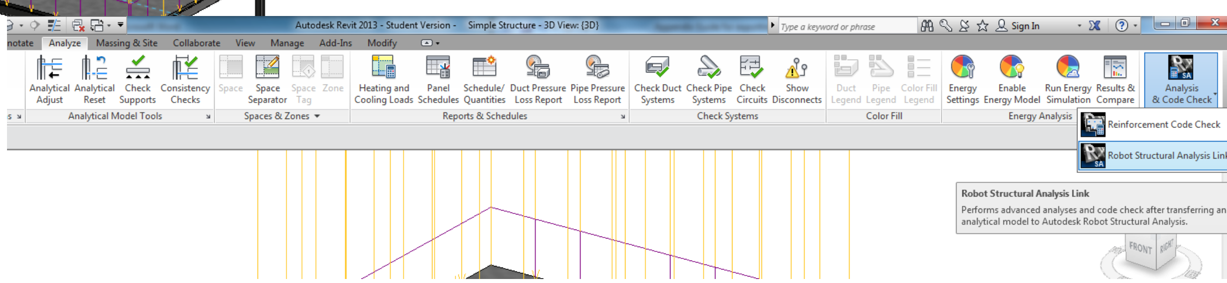


The files used for the simple export are simple “Simple Structure.rvt/.rtd”

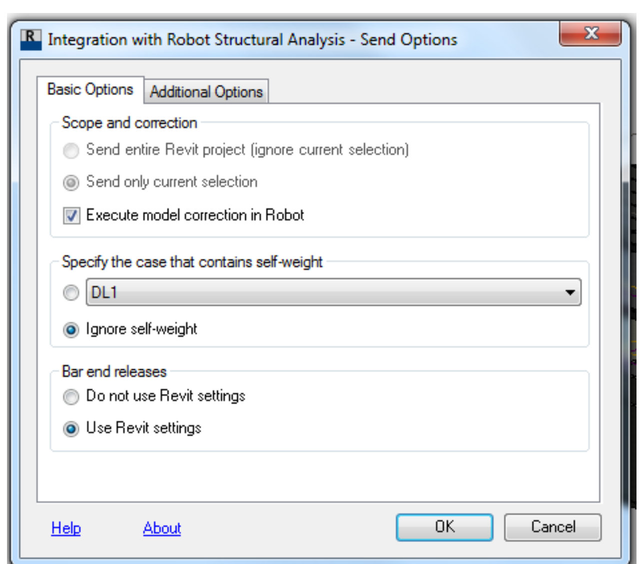
1. Using tools in *Revit*, the team created a simple bay with steel columns, girders, and open-web bar joists (left). The simple model also had steel decking and concrete on top of it.
2. Add loads using the **Analyze>Loads** function. For the simple structure, a dead load was added to represent the weight of the concrete on steel decking. Large point loads and one uniform area load were placed to ensure visible results in *Robot*.



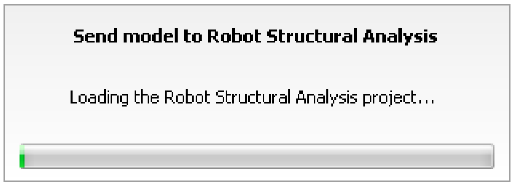
3. After a *Revit* project is complete and ready for structural analysis, the software enables users to export the analytical model to *Robot* where calculations of the loads can be better broken down. Choose **Analysis>Robot Structural Analysis Link** to export the model (below).



4. Once the *Robot* integration box is open (right), choose **Send Options**. Under **Basic Options**, executing model correction in *Robot* can help to ensure a smooth import. The St Vincent case could ignore self-weight because the loads from *Revit* included self-

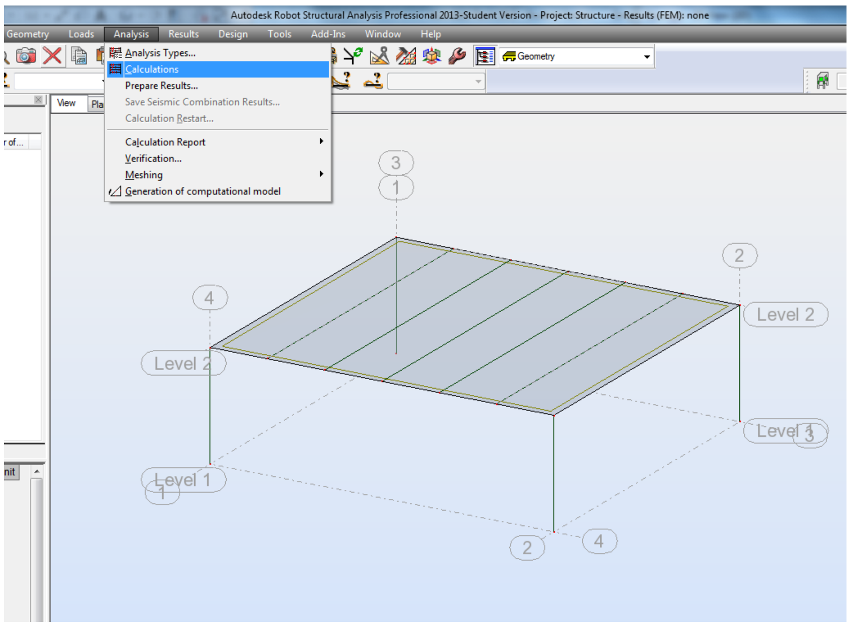


weights. Also, the bar end releases were set in *Revit* so use these settings.

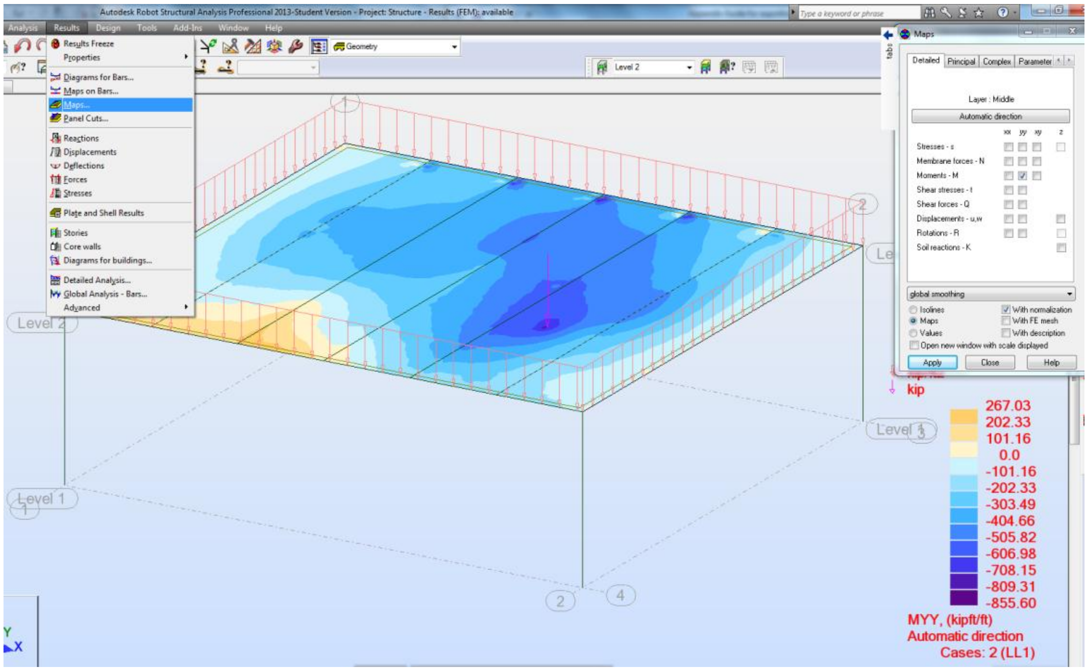


5. A progress box should pop up as the *Revit* model is exported to *Robot*, which displays each step of the transfer process (left).

6. Once the model is imported to *Robot*, the next step is to run calculations; this calculates the effects of all the loads individually on each member of the structure. Select **Analysis>Calculations** to begin this command (below).



7. *Robot* will run through various verifications, calculations, analysis, etc. After this process is complete, the results can be displayed on maps, tables, and graphs. For the St. Vincent case the team used MYY moment maps, which is displayed with **Results>Maps** (below). From here the user can examine the forces, moments, and displacements due to various default cases or custom cases. The analysis in this report used a custom case which factored the loads using ULS standards (explained in Appendix XXX).



Autodesk Robot Structural Analysis Professional 2013-Student Version - Project: Structure - Results (FEM): available
Results Freeze
Properties
Diagrams for Bars...
Maps on Bars...
Maps...
Panel Cuts...
Reactions
Displacements
Deflections
Forces
Stresses
Plate and Shell Results
Stories
Core walls
Diagrams for buildings...
Detailed Analysis...
Global Analysis - Bars...
Advanced
Maps
Detailed
Principal
Complex
Parameter
Layer : Middle
Automatic direction
Stresses - s
Membrane forces - N
Moments - M
Shear stresses - t
Shear forces - Q
Displacements - u,w
Rotations - R
Soil reactions - K
global smoothing
Isolines
Maps
Values
With normalization
With FE mesh
With description
Open new window with scale displayed
Apply
Close
Help
Level 2
Level 1
kip
267.03
202.33
101.16
0.0
-101.16
-202.33
-303.49
-404.66
-505.82
-606.98
-708.15
-809.31
-855.60
MYY, (kipft/ft)
Automatic direction
Cases: 2 (LL1)

Appendix I: Notes on Loads in *Revit* Baseline Model

Loads:

Roof:

- Snow = 38.5psf

Ground Floor on Slab on Grade = 250 psf
Vault Slabs subject to automobile traffic = 250 psf
Office Area = 100 psf
Mezzanine and Stairs = 100 psf
Mechanical penthouse = 150 psf

All dead loads for concrete on steel decking = 63 psf

Notes

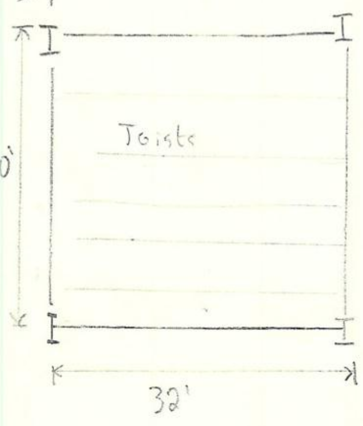
- All loads are place on the top of the floor surface
- *ROBOT* received error message to turn off kinematic constraints, so this was done.
- Iterative adjustment of the FE mesh was switched on due to an error message.
- Errors were received for the concrete casing around the base of the steel beams, so the concrete cover was removed from the columns.
- After reviewing article http://images.autodesk.com/adsk/files/linking_revit_structure_models_with_robot_structural_analysis.pdf pg 11 to change structural settings we were able to reduce warnings in Revit model from 167 to 49
- Deleted Robot self-weight calculation and used our values for dead weight.

Integrating Revit Structure and Robot Structural Analysis Professional. *Autodesk Revit Structure*, Retrieved from http://images.autodesk.com/adsk/files/linking_revit_structure_models_with_robot_structural_analysis.pdf

Appendix J: Open-Web Bar Joist Hand Calculations

32' x 30' Bays (100psf LL) 1

Bay:



Total Load = 163 psf   DL = 63 psf   LL = 100 psf

Assume joist + accessories weighs 10 PLF

Span 32'

6' spacing with 6 even spaces.

D: 6'(63 psf) + 10 plf => D = 388 plf

LL: 6'(100 psf) = 600 plf

Load Combinations:

D + H + F + L + T = 388 plf + 600 plf = 988 plf

From Vulcraft K-series Load Table

Max for 32' (span) = 549 lb/ft, so smaller spacing is required.

Vulcraft 5.7: Joists shall be spaced so that the load on each joist does not exceed the design load (ASD).

D: 4'(63 psf) = 252 + 10 pLF = 262 pLF

LL: 4'(100 psf) = 400 plf

Worst Case Load Combination:

D + L = 662 plf, Try smaller spacing

3 foot spacing

D: 3'(63 psf) = 189 + 10 plf = 199 plf

LL: 3'(100 psf) = 300 plf

Worst Case Load Combinations:

D + L = 499 plf

Total Load = 499 plf

Live load = Total load − Dead load

LL = 499 − 199 = 300 plf

Span 32'

Lightest Bar Joist Selection:

26 K9 => 12.2 lb/ft ← Use 26 K9 (lightest member)

30K 7 => 12.3 lb/ft.

22 K10 => 12.6 lb/ft

spaced at 3' => 10 even spaces

Bridging Requirements for 26K9 @ 3' spanning 32'

Vulcraft pg. 9 → Section number = 9, Joist spacing = 3' } $\frac{1}{2}$" Diameter

r = .13"

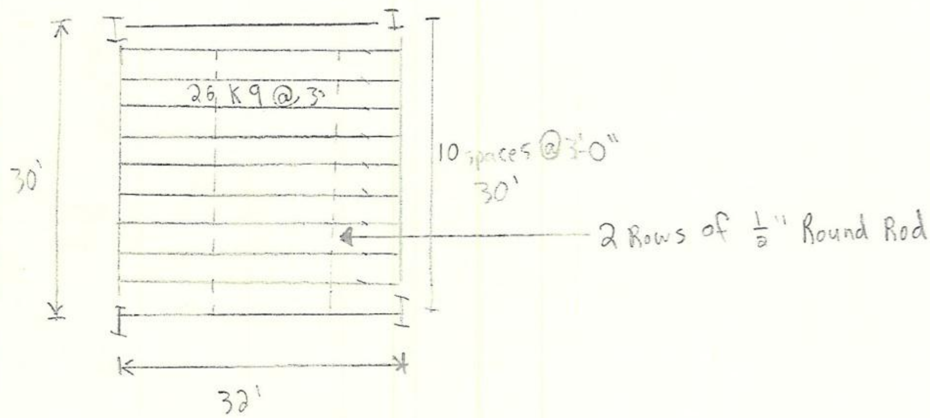
Good for up to 3.'3"

Bridging is $\frac{1}{2}$" Round Rod

Bridging Spacing:

Vulcraft pg. 43

Two Rows of bridging are needed for 26K9 spanning 32' @ 3' o.c.

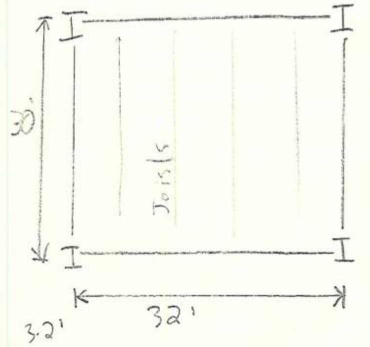


Note:

It is best to orient the joists in the short direction for strength. This method was explored and it can be found that it is not the most economical design.

This design requires 3,513.6 lbs of joists

To ensure the most economical design, try spanning the joists both ways. This analysis is for spanning the joist in the short direction.



Total Load = 163 psf DL = 63 psf LL = 100 psf

Try 4' Spacing

D: 4' (63 psf) = 252 + 10 pLf = 262 pLf   (estimate for joist)

LL: 4' (100 psf) = 400 pLf

Load too high, try smaller spacing.

3.2'
3'2.4" Spacing:

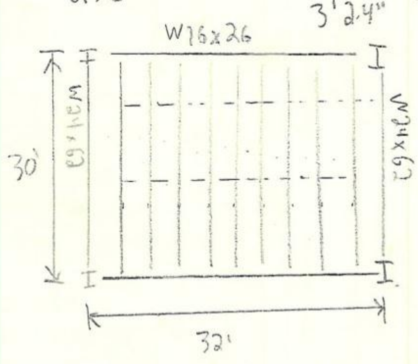
D: 3.2 (63 psf) + 10 = 211.6 pLf   (estimate for joist)

LL: 3.2 (100 psf) = 320 pLf

D + L = 531.6 pLf for 3.2' spacing spanning 30'

Possible joists:	Total Load	Live Load	Weight/ft:
20 K 10	533	336	12.2
22 K 10	550	385	12.6
24 K 9	544	419	12.0 ← Lightest Selection
26 K 8	544	457	12.1
~~28 K 7~~	~~531~~ × Fail	~~486~~	~~11.8~~

Use 24 K 9 @ 3.2' spacing
3'2.4"



Bridging Requirements: (Vulcraft Pg# 9:)

Section number = 9 }
Spacing = 3'2.4" } $\frac{1}{2}$" Diameter

r = .13"

Bridging is $\frac{1}{2}$" Round Rod

Two Rows of Bridging needed (Vulcraft Pg. 43)

This design = 3,240 lbs of steel for Joists

Try 3.55' spacing = 3'6.67" Spanning 30'

D: 3.55' (63psf) = 224 pLf

LL: 3.55' (100psf) = 356 pLf

D+LL = 580 ← Load to large, therefor spacing must be less than 3.55'.

We have already design bar joists for 10 even spaces of 24 K9 @ 3.2' spacing, now we shall examine even smaller spacing and choose the most economical design.

Try 12 spaces @ 2.67' Spanning 30'

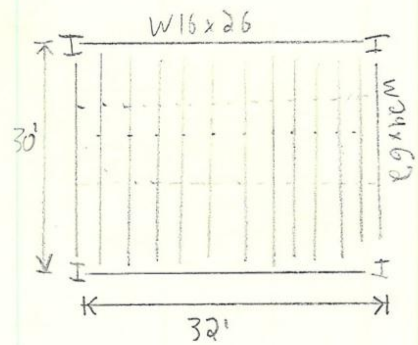
D: 2.667 (63psf) = 168 pLf

LL: 2.667 (100psf) = 267 pLf

Worst case Load:

D + LL = 435 pLf

Possible Joists:	Total Load	Live Load	lbs Weight/Ft
18 K 10	477	269	11.7
20 K 9	450	286	10.8
24 K 7	453	353	10.1 ← Use 24 K 7
26 K 6	441	377	10.6



24 K 7 @ 2.67' for 12 even spans.

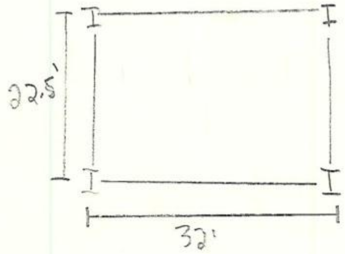
Bridging is $\frac{1}{2}$" Round Rod

Need 2 Rows of Bridging (Vulcraft Pg. 49)

This design calls for 3,333 lbs of steel.

This is more than the previous design with 24 K 9 @ 3.2'.

Design of 22'6" x 32' Office Bays



Span Joists in short direction for Strength:
4' spacing still would have a load larger than any K-series Joist provides.

Use 3.2' spacing

D: 211.6 pLF
LL: 320 pLF
} Total Load = 531.6 pLF

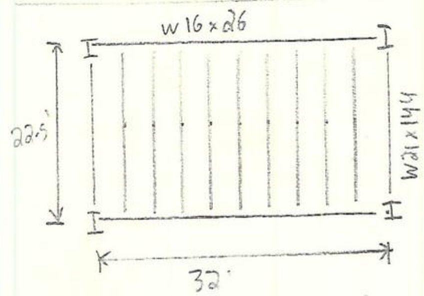
For 3.2' Spacing spanning 22.5'

Joists	Load	Live Load	Weight lbs/ft	Span
16K7	550	385	8.6	22'
	507	339	"	23'
	528.5 x Fails		"	22.5'
18K6	550	438	8.5	22'
	516	393	"	23'
	533	415.5	8.5	22.5' ✓
20K5	550	490	8.2	22'
	529	451	"	23'
	539.5	470.5	"	22.5' ✓
22K4	550	548	8	22'
	518	491	"	23'
	534	519.5	8	22.5' ✓

(Note: Interpolation was used to find Load and Live Load at 22.5' spans)

Lightest Member

22 K 4 @ 3.2' spacing, 10 even spaces.



1,620 lbs of Steel Joists

30'x30' Bays

DL=63psf LL=100psf

Joists Span 30'

Assumed weight of beam

Try 5' spacing: D: 5'(63psf) + 12 plf = 388 plf
LL: 5'(100psf) = 500 plf
} Loads to high for 30' spans

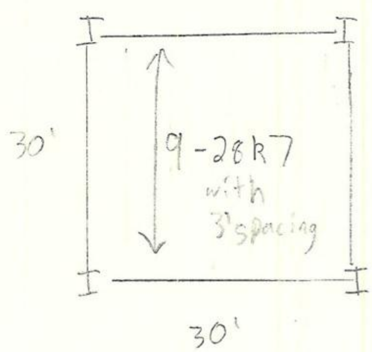
Try 3.75' spacing: D: 3.75'(63psf) + 12plf = 248.25plf
LL = 3.75'(100psf) = 375 plf
D+LL = 623.25 ... still to high for 30' spans

Try $3\frac{1}{3}$' Spacing: (Results still to high)

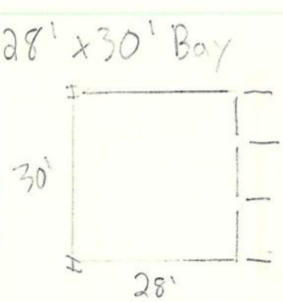
Try 3' spacing: D = 3(63psf) + 12plf = 201plf
LL = 300 plf
D+LL = 501 plf

Possible Joists	Load	Live Load	Weight lb/ft	Span
28K7	531	486	11.8	30'
24K9	544	419	12	30'

← Use 28K7 @ 3' spacing



28' x30' Bay   Span in short direction = 28'



Max L = 550, LL=543 for 28' spacing
However this is not possible for the bay, so try spanning 30'

Try 3.5' spacing spanning 30':

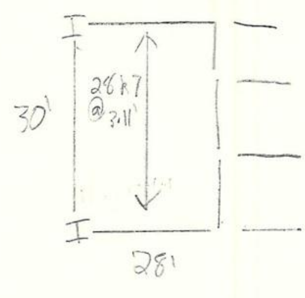
D: 3.5(63) + 10 (assumed) = 230.5 plf
LL: 3.5(100) = 350 plf } Loads to Large

Try 3.11' spacing:

D = 205.93 plf
LL = 311 plf   D+LL = 516.93 plf

Possible Joists	Load	Live Load	Weight lb/ft	Span
28K7	531	486	11.8	30' ← use
24K9	544	419	12.0	30'

Use 28K7 @ 3.11' spacing spanning 30'



2,832 lbs of steel

20'x28' Bays

Span joists 20' => Max L=550 plf; LL 550 plf

Try 8 joists spaced at 3.5'

D= 3.5'(63psf) + 10 = 230.5

LL=3.5'(100 psf) = 350 plf

D+LL = 580.5

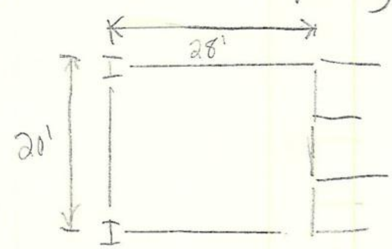
Try 9 joists spaced 3.11'

D = 205.93 plf   D+LL = 516.93 plf

LL = 311 plf

Possible Joists	Load	Live Load	Weight lb/ft	Span
14k6	525	347	7.7	20'
16k5	550	426	7.5	20' ← Use
20k4	550	520	7.6	20'

Use 16k5 @ 3.11' spacing



1,200 lbs of steel

Span 16.33': Maximum L=550 LL=534

Try spacing 3.2' for 32' span

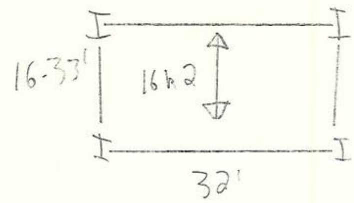
D: 3.2(63)+10 = 211.6 plf

LL: 3.2 (100psf) = 320 plf

D+LL = 531.6 plf

Possible Joists	Load	Live Load	Weight lb/ft	Span
16k2	550	550	5.5	16
	512	488	11	17
	537.33	529.33	5.5	16.33' ← Use

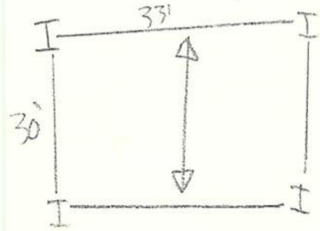
16k2 @ 3.2' at 10 even spaces



808.34 lbs of steel

(LL=100) 33x30 & 33x22'6" 10

33'x30' : Span = 30' Maximum L=550 Maximum LL = 543 plf



Try 10 spaces of 3.3'

D : 3.3'(63psf) + 10plf = 217.9plf

LL = 3.3'(100psf) = 330 plf

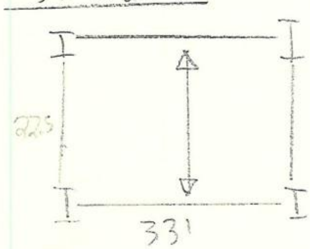
D + LL = 547.9 plf

Possible Joists	Load	Live Load	Weight lb/ft	Span
30 k 7	550	543	12.3	30 ft
26 k 9	550	459	12.2	30 ft ← Use
24 k 10	550	422	13.1	30 ft
22 k 10	550	385	12.6	30 ft

Use 26 k 9 @ 3.3' spacing

3,294 lbs of steel

33' x 22.5'



Span 22.5' Maximum L=555

Maximum LL = 533

Use 10 spaces of 3.3'

D = 217.9 plf LL = 330 plf.

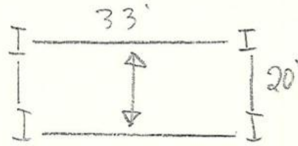
D + LL = 547.9 plf

Possible Joists	Load	Live Load	Weight lb/ft
22 k 5	550	533	8.8 ← Use
20 k 6	550	470.5	8.9

Use 22 k 5 @ 3.3' spacing

1,782 lbs of steel

33'x20' Span = 20' Maximum L= 550
Maximum LL= 550



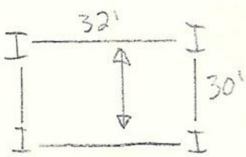
Try 10 spaces at 3.3'
D= 217.9 plf LL= 330 plf
D + LL= 547.9 plf

Possible Joists	Load	Live Load	Weight lb/ft.
20k4	550	550	7.6
18k4	550	490	7.2 ← Use
16k5	550	426	7.5

Use 18k4 @ 3.3' spacing

32'x20'

Spanning 30' Maximum D=550
Maximum LL= 543



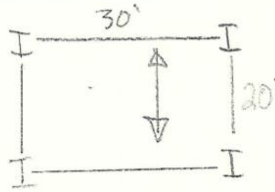
Use 3.2' spacing
D= 211.6 plf LL=320 plf
D + LL = 531.6

Possible Joists	Load	Live Load	Weight lb/ft
30k7	550	543	12.3
26k8	544	457	12.1
24k9	544	419	12.0 ← Use

Use 24k9 @ 3.2' spacing

3,240 lbs of steel

(LL=100) 30x20 12



Span 20' Maximum D = 550

Maximum LL = 550

Try 3.33' spacing

$D = 3.33(63) + ?$ guess about 8 then check $= 210$ plf

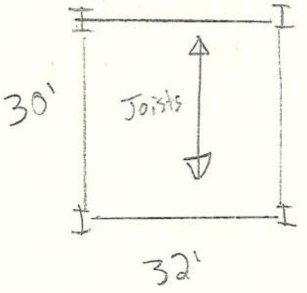
$LL = 3.33(100) = 333$

$LL + D = 543$

Possible Joists:	Load	Live Load	Weight lb/ft
20k4	550	550	7.6
18k4	550	490	7.2 ← Use

Use 8~ 18k4 @ 3.33' spacing

30'x32' Span 30'



Try 4' Spacing:

D: (2.14)(4') + 10 = 18.56 plf (Assumed)

LL: 127.75(4') = 511

D+LL = 529.56 plf

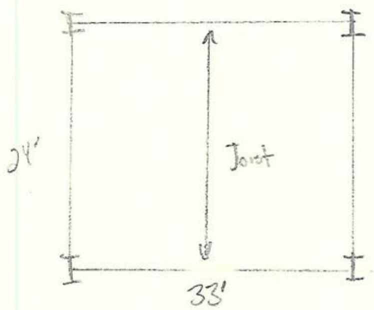
Maximum D = 550 > 529.56 ✓

Maximum Live Load = 543 > 511 ✓

Possible Joist	Total Load	Maximum Live Load	Weight/ft.
30K7	550	543	12.3 ← Use

30K7 @ 4' spacing

24'x33' span 24'



Try 5.5'

D: (2.14 psf)(5.5') + 10 psf = 21.77 (Assumed)

LL: 127.75 psf (5.5') = 702.625

D+LL = 724.395

MAX D = 550 > 724.4 ✗

Try 4.125' spacing

D: 2.14 (4.125') + 10 psf = 18.82

LL: 127.75 (4.125') = 526.96

D+LL = 545.79 plf

MAX D = 550 > 545.79 ✓

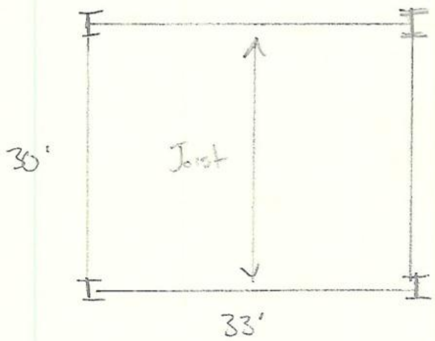
MAX LL = 544 > 526.96 ✓

(LL=127.75) 30'x33' 2

Possible Joist	Total Load	Live Load	Weight/ft	
24K5	550	544	9.3	← USE

24K5 @ 4.125' spacing

30' x 33' span 30'



Try 4.125' spacing

D = 2.14 (4.125') + 10 = 18.82
LL = 127.75 (4.125') = 526.96

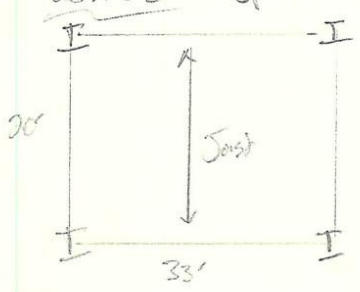
D+LL = 545.79 plf

MAX D = 550 > 545.79 ✓
MAX LL = 543 > 526.96 ✓

Possible Joist	Total Load	Live load	Weight/ft	
30K7	550	543	12.3	← Use

30K7 @ 4.125' spacing

20 x 33' span 20'



Try 4.125 spacing

D: 2.14 (4.125') + 10 = 18.82
LL: 127.75 (4.125) = 526.96

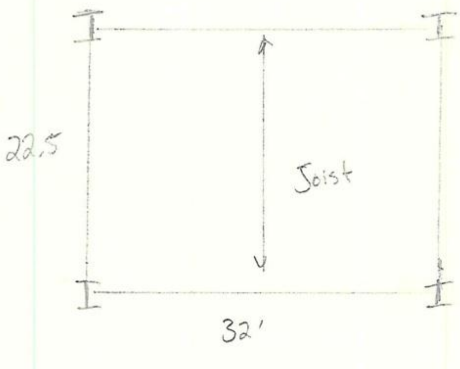
D+LL = 545.79

MAX D = 550 > 545.79 ✓
MAX LL = 550 > 526.96 ✓

Possible Joist	Total Load	Live load	weight/ft	
20K10	550	550	12.2	
20K4	550	550	7.6	← USE

20K4 @ 4.125' spacing

22.5' x 32'   span 22.5



Try 4' spacing

$D = 2.14(4') + 10 = 18.56$ plf

$LL = 127.75(4') = 511$

$D + LL = 529.56$ plf

Max $D = 550 > 529.56$ ✓

Max $LL = 548 - 518 = \frac{30}{2} = 15$

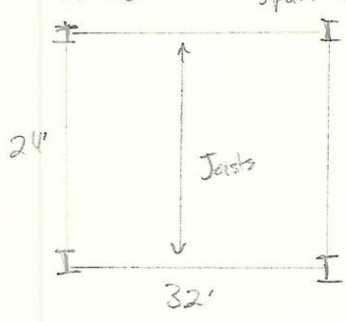
$548 - 15 = 533$

$533 > 511$ ✓

Possible Joist	Total Load	Live load	weight/ft	span
22K5	550	548	8.8	22'
	550	518	8.8	23'
	550	533	8.8	22.5 ← Use
22K4	550	548	8	22'
	518	491	8	23'
	534	FAILS 519.5	8	22.5' X

22K5 @ 4' spacing

32 x 24'   span 24



Try 4' spacing

$D = 2.14(4') + 10 = 18.56$ plf

$LL = 127.75(4') = 511$

$D + LL = 529.56$ plf

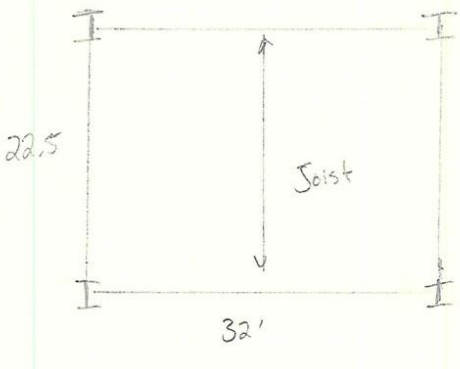
MAX $D = 550 > 529.56$ ✓

MAX $D = 544 > 511$ ✓

Possible Joist	Total load	Live load	weight/ft
24K12	550	544	16.0 X
24K10	550	544	13.1
24K9	550	544	12
24K5	550	544	9.3 ← Use

24K5 @ 4' spacing

22.5' x 32' span 22.5



Try 4' spacing

D = 2.14(4') + 10 = 18.56 plf
LL = 127.75(4') = 511

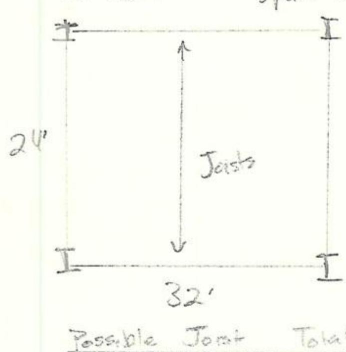
D+LL = 529.56 plf

Max D = 550 > 529.56 ✓
Max LL = 548 - 518 = $\frac{30}{2}$ = 15
548 - 15 = 533
533 > 511 ✓

Possible Joist	Total Load	Live load	weight/ft	span
22K5	550	548	8.8	22'
	550	518	8.8	23'
	550	533	8.8	22.5 ← Use
22K4	550	548	8	22'
	518	491	8	23'
	534	FAILS 519.5	8	22.5' X

22K5 @ 4' spacing

32 x 24' span 24



Try 4' spacing

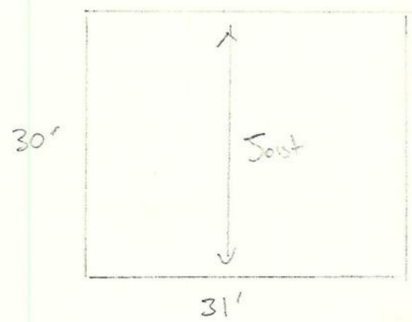
D = 2.14(4') + 10 = 18.56 plf
LL = 127.75(4') = 511
D+LL = 529.56 plf

MAX D = 550 > 529.56 ✓
MAX D = 544 > 511 ✓

Possible Joist	Total load	Live load	Weight/Ft	
24K12	550	544	16.0	X
24K10	550	544	13.1	
24K9	550	544	12	
24K5	550	544	9.3	← Use

24K5 @ 4' spacing

31' × 30' span 30'



Try 4.42 spacing X

D: 63 psf (4.42) + 10 = 288 plf
LL: 127.75 (4.42) = 564.65

D+LL = 853.11 TOO BIG

Try 3.875' spacing X

D: 63 psf (3.875) + 10 = 254.125
LL: 127.75 × 3.875 = 495.031
D+LL = 749.15

Try 2.58' spacing

D: 63 (2.58) + 10 = 172.54
LL: 127.54 (2.58) = 329.595
D+LL = 502.135 POSSIBLE

MAX D = 550 > 502.13 ✓
MAX LL = 543 > 329.6 ✓

Try 2.82' spacing

D: 63 (2.82) + 10 = 187.54
LL: 127.75 (2.82) = 360.023
D+LL = 547.56

MAX D : 550 > 547.56 ✓
MAX LL : 543 > 360.023 ✓

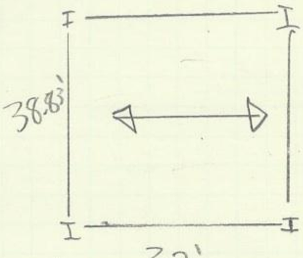
Possible Joist	Total Load	Live load	weight/ft
30K7	550	543	12.3
28K8	550	500	12.7
26K9	550	459	12.2 ← USE
24K10	550	422	13.1
22K10	550	385	12.6

26K9 @ 2.82' spacing

	32×38.83 30	Mech Roof	5

Use Snow Load of $p_f = 38.5$ and do not use drift as this portion is elevated.

38'10" (38.83̄') × 32' Bay:



Span short direction = 32'

Maximun D = 549, LL = 500

Maximum spacing = 10' Try 9.71' spacing

$D = 9.71(2.14) + 10 = 30.78$ plf

$LL = 9.71(38.5) = 373.84$ plf

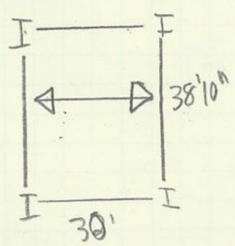
$D + LL = 404.62$ plf

1,132.8 lbs of steel

Possible Jois	Load	Live Load	Weight lb/ft
28k7	466	400	11.8 ← use
26k8	477	375	12.1

use 3 28k7 @ 9.71'

38'10" × 30'



Span 30' Maximum Load = 550, LL = 543

Try 9.71' Spacing

$D = 30.78$ plf $LL = 373.84$ plf $D + LL = 404.62$ plf

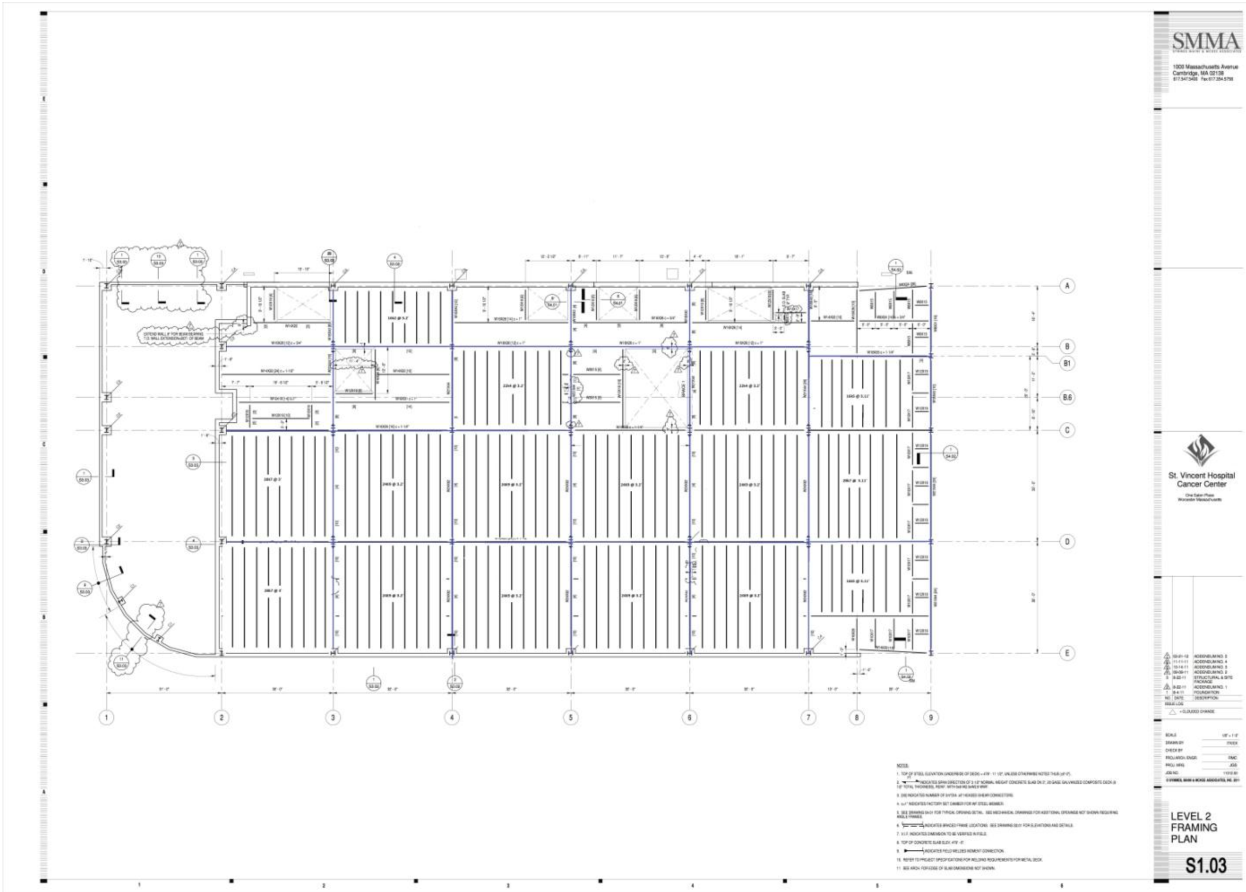
Possible Joist	Load	Live Load	Weight lb/ft
28k6	477	439	11.4
26k6	441	377	10.6 ← use

Use 26k6 @ 9.71' spacing

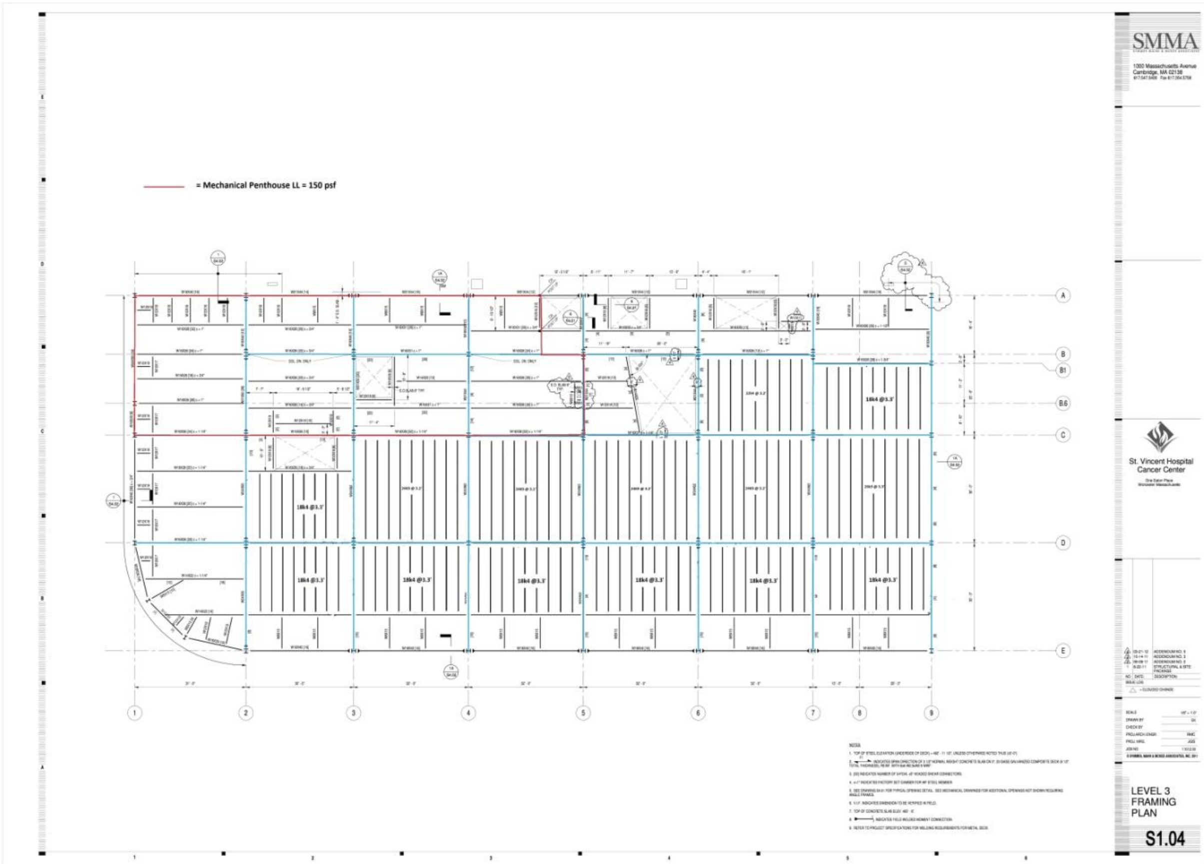
954 lbs of steel

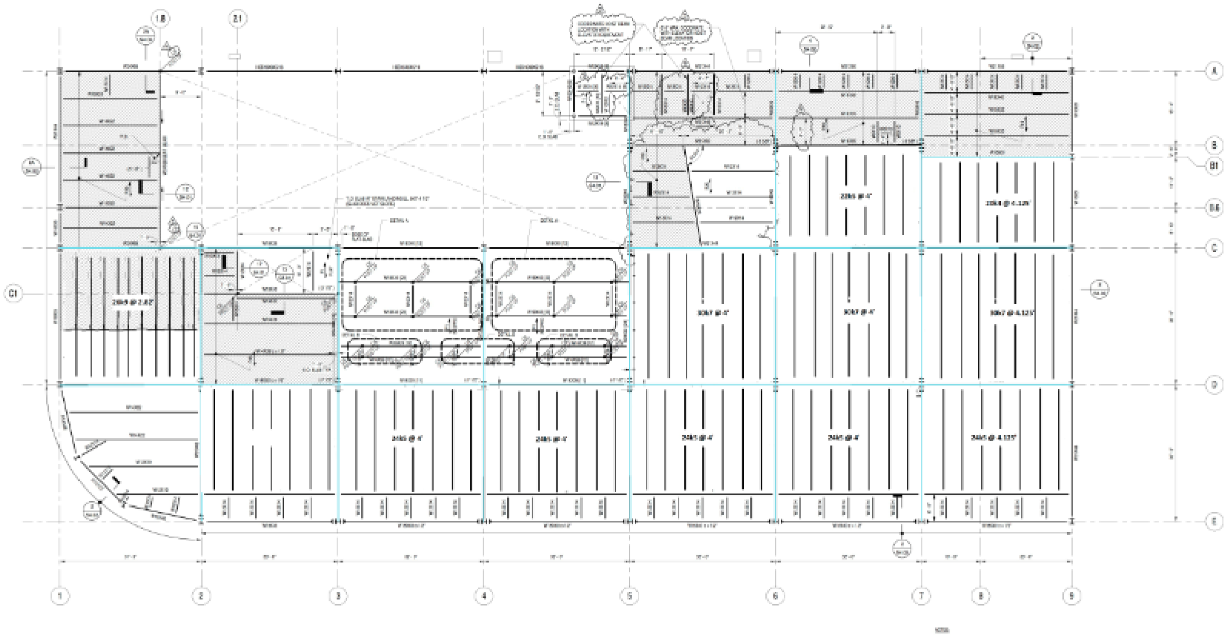
Appendix K: Proposed Open-Web Bar Joist Designs

Bay Area	Live Load	Proposed Bar Joist	Weight (lb/ft)	Span Length (ft)	Spacing (ft)	Number of Joists	Lbs of Steel Joists	Reference Page
32x30	100	24k9	12	30	3.2	9	3240	3
32x22.5	100	22K4	8	22.5	3.2	9	1620	5
30x30	100	28k7	11.8	30	3	9	3186	6
28x30	100	28k7	11.8	30	3.11	8	2832	7
28x20	100	16k5	7.5	20	3.11	8	1200	8
32x16.33	100	16k2	5.5	16.33	3.2	9	808.335	9
32x20	100	24k9	12	30	3.2	9	3240	11
33X30	100	26k9	12.2	30	3.3	9	3294	10
33X22.5	100	22k5	8.8	22.5	3.3	9	1782	10
33X20	100	18k4	7.2	20	3.3	9	1296	11
32X20	100	26K9	7.2	20	3.3	9	1296	9
30x20	100	18k4	7.2	20	3.3	8	1152	12
30X22.5	100	26K9	12.2	22.5	3.3	8	2196	9
30X24	100	24K4	8.4	24	3.75	7	1411.2	6B
30x32	127.75	30k7	12.3	30	4	7	2583	1B
24X33	127.75	24k5	9.3	24	4.125	7	1562.4	1B
30X33	127.75	30k7	12.3	30	4.125	7	2583	2B
20X33	127.75	20k4	7.6	20	4.125	7	1064	2B
22.5X32	127.75	22k5	8.8	22.5	4	7	1386	3B
32X24	127.75	24k5	9.3	24	4	7	1562.4	3B
31X30	127.75	26k9	12.2	30	2.82	10	3660	4B
38.83x32	38.5	28k7	11.8	32	9.71	3	1132.8	5B
38.83x30	38.5	26k6	10.6	30	9.71	3	954	5B
							0	
							0	
Roof Lbs of Open-Web Bar Joists							14400.8	
1st and 2nd Floors Lbs of Open-Web Bar Joists							23650.335	
Total Weight of Proposed Open-Web Bar Joists							45041.135	



SMMA
1000 Massachusetts Avenue
Cambridge, MA 02138
St. Vincent Hospital
Cancer Center
LEVEL 2
FRAMING
PLAN
S1.03


= Mechanical Penthouse LL = 150 psf
SMMA
St. Vincent Hospital Cancer Center
LEVEL 3 FRAMING PLAN
S1.04



30K7 @ 4'
30K7 @ 4'
30K7 @ 4.125'
24K5 @ 4'
24K5 @ 4'
24K5 @ 4'
24K5 @ 4'
24K5 @ 4.125'
22K6 @ 4'
A
B
B1
C
D
E
1
2
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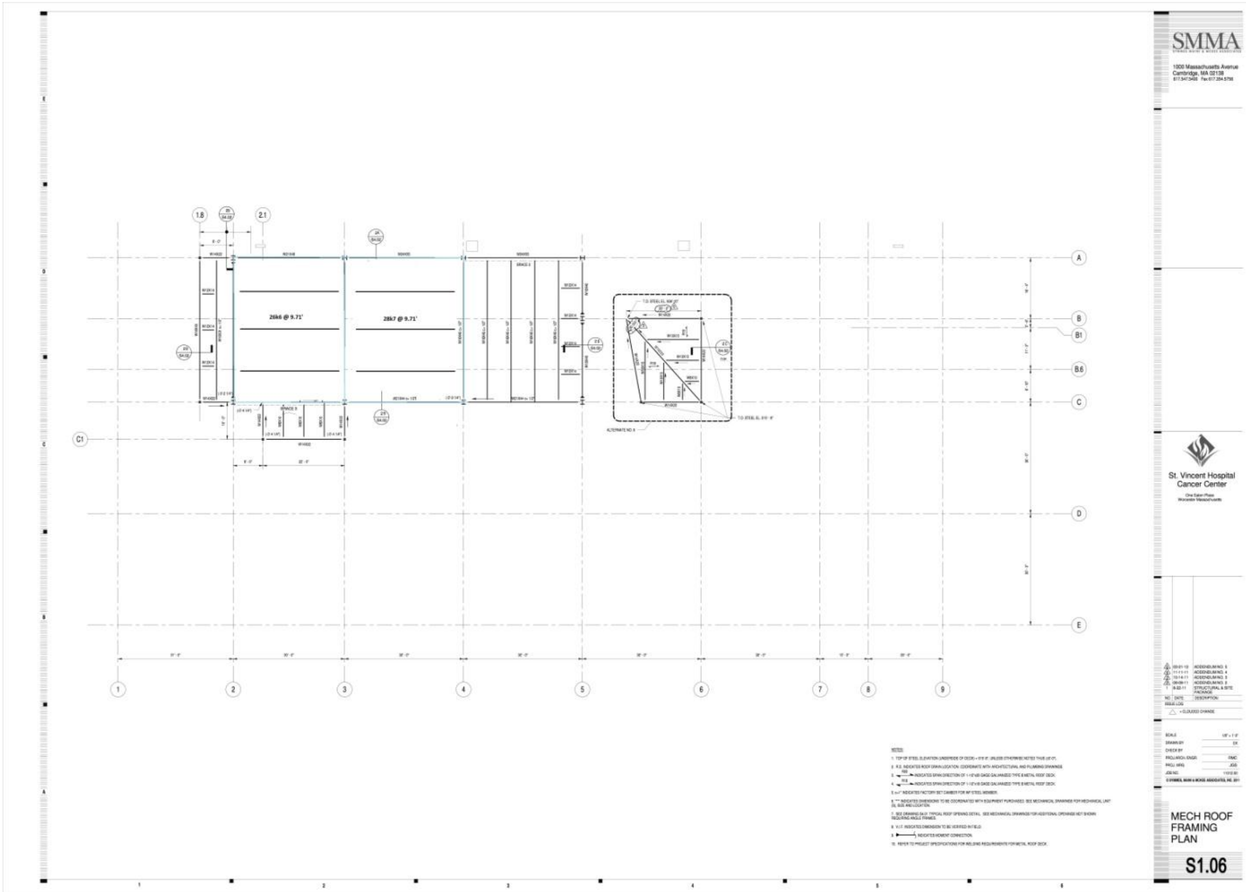
SMMA
1000 Massachusetts Avenue
Cambridge, MA 02138
St. Vincent Hospital
Cancer Center
MECH ROOF
FRAMING
PLAN
S1.06

Appendix L: Concrete Member Baseline Costs

Concrete

Wall Schedule	cost per CY (Subcontractor)		$446.01	
Family and Type	Volume (CY)	Total Cost	RS Means	
			Cost per CY	Total Cost
Basic Wall: Foundation 1-0	9.21	$4,107.80	$540.00	$4,973.40
Basic Wall: Foundation	8.58	$3,826.81	$540.00	$4,633.20
Basic Wall: Foundation 1-0	6.05	$2,698.39	$540.00	$3,267.00
Basic Wall: Foundation	2.34	$1,043.67	$540.00	$1,263.60
Basic Wall: Foundation	13.5	$6,021.20	$540.00	$7,290.00
Basic Wall: Foundation	5.51	$2,457.54	$540.00	$2,975.40
Basic Wall: Foundation	15.96	$7,118.40	$540.00	$8,618.40
Basic Wall: Foundation	15.61	$6,962.29	$540.00	$8,429.40
Basic Wall: Foundation	5.04	$2,247.91	$540.00	$2,721.60
Basic Wall: Foundation 1-0	18.29	$8,157.61	$540.00	$9,876.60
Basic Wall: Foundation 1-0	9.58	$4,272.82	$540.00	$5,173.20
Basic Wall: Foundation 1-0	46.02	$20,525.60	$540.00	$24,850.80
Basic Wall: Foundation	10.26	$4,576.11	$540.00	$5,540.40
Basic Wall: Foundation 1-0	23.88	$10,650.83	$540.00	$12,895.20
Basic Wall: Foundation	1.43	$637.80	$540.00	$772.20
Basic Wall: Foundation 1-0	3.28	$1,462.93	$540.00	$1,771.20
Basic Wall: Foundation 1-0	46.18	$20,596.96	$540.00	$24,937.20
Basic Wall: Foundation	7.86	$3,505.68	$540.00	$4,244.40
Basic Wall: Foundation 1-6	19.91	$8,880.15	$540.00	$10,751.40
Basic Wall: Foundation 1-6	1.3	$579.82	$540.00	$702.00
Basic Wall: Foundation 1-4	12.07	$5,383.40	$540.00	$6,517.80
Basic Wall: Foundation 1-4	0.69	$307.75	$540.00	$372.60
Basic Wall: Foundation 1-0	19.47	$8,683.91	$540.00	$10,513.80
Basic Wall: Foundation 1-0	1.12	$499.54	$540.00	$604.80
Basic Wall: Foundation 1-0	1.57	$700.24	$540.00	$847.80
Basic Wall: Foundation 1-0	1.06	$472.78	$540.00	$572.40
Basic Wall: Foundation 1-0	3.91	$1,743.92	$540.00	$2,111.40
Basic Wall: Foundation 1-0	2.21	$985.69	$540.00	$1,193.40
Basic Wall: Foundation 1-0	1.94	$865.27	$540.00	$1,047.60
Basic Wall: Foundation 1-0	3.58	$1,596.73	$540.00	$1,933.20
Basic Wall: Foundation 1-0	3.17	$1,413.87	$540.00	$1,711.80
Basic Wall: Foundation 1-4	4.84	$2,158.71	$540.00	$2,613.60
Basic Wall: Foundation 1-4	7.58	$3,380.79	$540.00	$4,093.20

Basic Wall: Foundation 1-0	9.52	$4,246.06	$540.00	$5,140.80
Basic Wall: Foundation 1-0	2.48	$1,106.12	$540.00	$1,339.20
Basic Wall: Foundation 1-0	5.92	$2,640.41	$540.00	$3,196.80
Basic Wall: Foundation 1-0	0.78	$347.89	$540.00	$421.20
Basic Wall: Foundation 1-0	1.78	$793.91	$540.00	$961.20
Basic Wall: Foundation 1-0	5.34	$2,381.72	$540.00	$2,883.60
Basic Wall: Foundation 1-0	7.28	$3,246.99	$540.00	$3,931.20
Basic Wall: Foundation 1-4	2.59	$1,155.18	$540.00	$1,398.60
Basic Wall: Foundation 1-4	6.69	$2,983.84	$540.00	$3,612.60
Basic Wall: Foundation 1-0	0.86	$383.57	$540.00	$464.40
Basic Wall: Foundation 1-4	3.43	$1,529.83	$540.00	$1,852.20
Basic Wall: Foundation 1-4	11.08	$4,941.84	$540.00	$5,983.20
Basic Wall: Foundation 1-4	50.87	$22,688.77	$540.00	$27,469.80
Basic Wall: Foundation 1-0	1.64	$731.46	$540.00	$885.60
Basic Wall: Foundation 1-0	1.22	$544.14	$540.00	$658.80
Basic Wall: Foundation 1-0	2.64	$1,177.48	$540.00	$1,425.60
Basic Wall: Foundation 1-0	0.67	$298.83	$540.00	$361.80
Basic Wall: Foundation 1-0	1.15	$512.92	$540.00	$621.00
Basic Wall: Foundation 1-0	0.67	$298.83	$540.00	$361.80
Basic Wall: Foundation 1-0	8.9	$3,969.53	$540.00	$4,806.00
Basic Wall: Foundation 8in	4.01	$1,788.52	$540.00	$2,165.40
Basic Wall: Foundation 8in	6.74	$3,006.14	$540.00	$3,639.60
Basic Wall: Foundation 1-0	0.58	$258.69	$540.00	$313.20
Basic Wall: Foundation 1-0	1.07	$477.24	$540.00	$577.80
Basic Wall: Foundation 1-0	0.71	$316.67	$540.00	$383.40
Basic Wall: Foundation 1-4	3.63	$1,619.03	$540.00	$1,960.20
Basic Wall: Foundation 1-4	18.29	$8,157.61	$540.00	$9,876.60
Basic Wall: Foundation 10in	0.94	$419.25	$540.00	$507.60
Basic Wall: Foundation 10in	1.14	$508.46	$540.00	$615.60
Basic Wall: Foundation 10in	0.86	$383.57	$540.00	$464.40
Basic Wall: Foundation 10in	0.94	$419.25	$540.00	$507.60
Basic Wall: Foundation 10in	1.13	$504.00	$540.00	$610.20
Basic Wall: Foundation 10in	0.86	$383.57	$540.00	$464.40
Basic Wall: Foundation 1-4	38.81	$17,309.83	$540.00	$20,957.40
Basic Wall: Foundation 1-4	14.96	$6,672.38	$540.00	$8,078.40
Basic Wall: Foundation 1-4	16.45	$7,336.94	$540.00	$8,883.00
Basic Wall: Foundation 1-4	0.95	$423.71	$540.00	$513.00
Basic Wall: L6	25.18	$11,230.65	$540.00	$13,597.20
Basic Wall: L10	54.19	$24,169.54	$540.00	$29,262.60
Basic Wall: L6	18.63	$8,309.26	$540.00	$10,060.20
Basic Wall: L2	96.09	$42,857.56	$540.00	$51,888.60
Basic Wall: L3	29.27	$13,054.85	$540.00	$15,805.80
Basic Wall: L8	15.97	$7,122.86	$540.00	$8,623.80

Basic Wall: L9	69.99	$31,216.58	$540.00	$37,794.60
Basic Wall: L8	36.69	$16,364.28	$540.00	$19,812.60
Basic Wall: L4	77.34	$34,494.78	$540.00	$41,763.60
Basic Wall: L3	34.89	$15,561.46	$540.00	$18,840.60
Basic Wall: L1	23.99	$10,699.89	$540.00	$12,954.60
Basic Wall: L1	108.19	$48,254.34	$540.00	$58,422.60
Basic Wall: Foundation 1-0	0.52	$231.93	$540.00	$280.80
Basic Wall: L1	10.97	$4,892.78	$540.00	$5,923.80
Basic Wall: L1	19.83	$8,844.47	$540.00	$10,708.20
Basic Wall: L1	23.78	$10,606.23	$540.00	$12,841.20
Basic Wall: Foundation	2.75	$1,226.54	$540.00	$1,485.00
Basic Wall: Foundation	3.02	$1,346.96	$540.00	$1,630.80
Basic Wall: Foundation	4.47	$1,993.69	$540.00	$2,413.80
Basic Wall: Foundation	4.16	$1,855.42	$540.00	$2,246.40
Basic Wall: Foundation 1-0	4.14	$1,846.50	$540.00	$2,235.60
Basic Wall: Foundation 1-0	4.48	$1,998.15	$540.00	$2,419.20
Basic Wall: Foundation 1-0	6.57	$2,930.32	$540.00	$3,547.80
Basic Wall: Foundation 1-0	6.18	$2,756.37	$540.00	$3,337.20
Basic Wall: L5	10.42	$4,647.47	$540.00	$5,626.80
Basic Wall: Foundation 2-6	26.5	$11,819.39	$540.00	$14,310.00
Basic Wall: Foundation 2-6	26.6	$11,863.99	$540.00	$14,364.00
Basic Wall: Foundation 2-6	26.5	$11,819.39	$540.00	$14,310.00
Basic Wall: Foundation 2-6	26.6	$11,863.99	$540.00	$14,364.00
Basic Wall: L6	10.7	$4,772.36	$540.00	$5,778.00
Basic Wall: L6	19.82	$8,840.01	$540.00	$10,702.80
Basic Wall: Foundation 2-0	17.58	$7,840.94	$540.00	$9,493.20
Basic Wall: Foundation 2-0	17.82	$7,947.98	$540.00	$9,622.80
Basic Wall: L6	17.8	$7,939.06	$540.00	$9,612.00
Basic Wall: Foundation 2-0	17.58	$7,840.94	$540.00	$9,493.20
Basic Wall: Foundation 2-0	17.82	$7,947.98	$540.00	$9,622.80
Basic Wall: L5	21.77	$9,709.74	$540.00	$11,755.80
Basic Wall: Foundation 5-0	49.86	$22,238.30	$540.00	$26,924.40
Basic Wall: L7	54.19	$24,169.54	$540.00	$29,262.60
Basic Wall: Foundation 1-0	0.46	$205.17	$540.00	$248.40
Basic Wall: Foundation 1-4	53.86	$24,022.36	$540.00	$29,084.40
Basic Wall: Foundation 1-4	6.18	$2,756.37	$540.00	$3,337.20
Basic Wall: L6	0.85	$379.11	$540.00	$459.00
Basic Wall: L6	14.32	$6,386.93	$540.00	$7,732.80
Total (CY)	1689.1	$753,363.59		$912,114.00

Structural Foundation Schedule	cost per CY	$446.01

Family and Type	Volume (CY)	Total Cost	RS Means Cost per CY	RS Means Total Cost
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F9	6.5	$2,899.10	$360.00	$2,340.00
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F9	6.5	$2,899.10	$360.00	$2,340.00
Footing-Rectangular: F10	8.02	$3,577.04	$360.00	$2,887.20
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F11	10.46	$4,665.31	$360.00	$3,765.60
Footing-Rectangular: F20	22.22	$9,910.45	$360.00	$7,999.20
Footing-Rectangular: F20	22.22	$9,910.45	$360.00	$7,999.20
Footing-Rectangular: F9	6.5	$2,899.10	$360.00	$2,340.00
Footing-Rectangular: F10	8.02	$3,577.04	$360.00	$2,887.20
Corner 9E Footing: 72" x 48" x 18"	87.59	$39,066.44	$360.00	$31,532.40
Wall Foundation: Line E footing	0.72	$321.13	$540.00	$388.80
Wall Foundation: Line E footing	1.65	$735.92	$540.00	$891.00
Wall Foundation: Line E footing	0.79	$352.35	$540.00	$426.60
Wall Foundation: Line E footing	3.56	$1,587.81	$540.00	$1,922.40
Wall Foundation: Line E footing	1.09	$486.16	$540.00	$588.60
Wall Foundation: Line E footing	3.52	$1,569.97	$540.00	$1,900.80
Wall Foundation: Line E footing	0.37	$165.03	$540.00	$199.80
Wall Foundation: Line E footing	3.76	$1,677.02	$540.00	$2,030.40
Wall Foundation: Line E footing	0.69	$307.75	$540.00	$372.60
Wall Foundation: Line E footing	0.41	$182.87	$540.00	$221.40
Wall Foundation: Line E footing	3.76	$1,677.02	$540.00	$2,030.40
Wall Foundation: Line E footing	0.68	$303.29	$540.00	$367.20
Wall Foundation: Line E footing	0.14	$62.44	$540.00	$75.60
Wall Foundation: Line 8 footing	4.86	$2,167.63	$540.00	$2,624.40
Footing-Rectangular: F5	1.23	$548.60	$360.00	$442.80
Wall Foundation: DC near 9 footing	4.89	$2,181.01	$540.00	$2,640.60
Wall Foundation: Line C stair area	0.94	$419.25	$540.00	$507.60
Wall Foundation: Line C stair area	1.24	$553.06	$540.00	$669.60
Wall Foundation: 4 ft x 1ft thick	5.63	$2,511.06	$540.00	$3,040.20

Wall Foundation: 4 ft x 1ft thick	0.74	$330.05	$540.00	$399.60
Wall Foundation: 4 ft x 1ft thick	0.56	$249.77	$540.00	$302.40
Wall Foundation: Line C stair area	2.22	$990.15	$540.00	$1,198.80
Wall Foundation: Line C stair area	2.2	$981.23	$540.00	$1,188.00
Wall Foundation: Line C stair area	1.36	$606.58	$540.00	$734.40
Wall Foundation: Stair Area Jut Out	0.69	$307.75	$540.00	$372.60
Wall Foundation: Stair Area Jut Out 2	0.03	$13.38	$540.00	$16.20
Footing-Rectangular: F8	4.74	$2,114.11	$360.00	$1,706.40
Wall Foundation: Line A vault	0.74	$330.05	$540.00	$399.60
Wall Foundation: Line A vault	2.3	$1,025.83	$540.00	$1,242.00
Wall Foundation: 4 ft x 1ft thick 2	2.86	$1,275.60	$540.00	$1,544.40
Wall Foundation: 4 ft x 1ft thick	0.73	$325.59	$540.00	$394.20
Wall Foundation: Line B B1 stair	1.01	$450.47	$540.00	$545.40
Wall Foundation: 4 ft x 1ft thick	0.07	$31.22	$540.00	$37.80
Wall Foundation: Line A vault	5.98	$2,667.17	$540.00	$3,229.20
Wall Foundation: Line A vault	0.41	$182.87	$540.00	$221.40
Wall Foundation: Line A vault 2	3.68	$1,641.33	$540.00	$1,987.20
Wall Foundation: Elevator footing	1.74	$776.07	$540.00	$939.60
Wall Foundation: Elevator footing	1.44	$642.26	$540.00	$777.60
Wall Foundation: Elevator footing	0.24	$107.04	$540.00	$129.60
Wall Foundation: Elevator footing	1.71	$762.69	$540.00	$923.40
Wall Foundation: Elevator footing	1.47	$655.64	$540.00	$793.80
Wall Foundation: Elevator footing	1.17	$521.84	$540.00	$631.80
Wall Foundation: Line A vault	1.63	$727.00	$540.00	$880.20
Wall Foundation: Garage	22.13	$9,870.31	$540.00	$11,950.20
Wall Foundation: Garage	27.75	$12,376.91	$540.00	$14,985.00
Wall Foundation: Garage	25.47	$11,360.00	$540.00	$13,753.80
48" Foundation Slab	586.81	$261,725.94	$50.00	$29,340.50
12" Foundation Slab	7.9	$3,523.52	$13.15	$103.89
18" Foundation Slab	17.97	$8,014.89	$15.50	$278.54
18" Foundation Slab	4.14	$1,846.50	$15.50	$64.17

39" Foundation Slab	44.76	$19,963.62	$28.00	$1,253.28
39" Foundation Slab	35.25	$15,722.02	$28.00	$987.00
39" Foundation Slab	35.53	$15,846.91	$28.00	$994.84
Wall Foundation: Line A vault	6.19	$2,760.83	$540.00	$3,342.60
Wall Foundation: Line A vault	0.85	$379.11	$540.00	$459.00
Wall Foundation: Garage 2	14.26	$6,360.17	$540.00	$7,700.40
12" Foundation Slab	164.59	$73,409.57	$13.15	$2,164.36
12" Foundation Slab	3.78	$1,685.94	$13.15	$49.71
12" Foundation Slab	2	$892.03	$13.15	$26.30
12" Foundation Slab	2.31	$1,030.29	$13.15	$30.38
6" Foundation Slab	11.53	$5,142.55	$6.97	$80.36
5" Foundation Slab (SOG)	277.98	$123,983.19	$6.97	$1,937.52
Total (CY)	1622.1	$723,480.60		$221,888.24

Structural Column Schedule	Cost per CY	$446.01		
Family and Type	Volume (CY)	Total Cost	RS Means	
			Cost per CY	Total Cost
Concrete-Rectangular-Column: 1	4.63	$2,065.05	$2,425.00	$11,227.75
Concrete-Rectangular-Column: 2	2.61	$1,164.10	$2,425.00	$6,329.25
Concrete-Rectangular-Column: 2	2.61	$1,164.10	$2,425.00	$6,329.25
Concrete-Rectangular-Column: 2	2.61	$1,164.10	$2,425.00	$6,329.25
Concrete-Rectangular-Column: 2	2.61	$1,164.10	$2,425.00	$6,329.25
Concrete-Rectangular-Column: 2	2.61	$1,164.10	$2,425.00	$6,329.25
Concrete-Rectangular-Column: 2	2.77	$1,235.46	$2,425.00	$6,717.25
Concrete-Rectangular-Column: 2	3	$1,338.04	$2,425.00	$7,275.00
Concrete-Rectangular-Column: 2	0.48	$214.09	$2,425.00	$1,164.00
Concrete-Rectangular-Column: 3	0.9	$401.41	$2,425.00	$2,182.50
Concrete-Rectangular-Column: 3	0.87	$388.03	$2,425.00	$2,109.75

Concrete-Rectangular-Column: 3	0.87	$388.03	$2,425.00	$2,109.75
Concrete-Rectangular-Column: 4	0.53	$236.39	$2,425.00	$1,285.25
Concrete-Rectangular-Column: 2	0.57	$254.23	$2,425.00	$1,382.25
Concrete-Rectangular-Column: 2	0.58	$258.69	$2,425.00	$1,406.50
Concrete-Rectangular-Column: 2	0.55	$245.31	$2,425.00	$1,333.75
Concrete-Rectangular-Column: 2	0.55	$245.31	$2,425.00	$1,333.75
Concrete-Rectangular-Column: 2	2.19	$976.77	$2,425.00	$5,310.75
Concrete-Rectangular-Column: 2	1.95	$869.73	$2,425.00	$4,728.75
Concrete-Rectangular-Column: 2	2.08	$927.71	$2,425.00	$5,044.00
Concrete-Rectangular-Column: 2	1.99	$887.57	$2,425.00	$4,825.75
Concrete-Rectangular-Column: 2	2.01	$896.49	$2,425.00	$4,874.25
Concrete-Rectangular-Column: 2	1.34	$597.66	$2,425.00	$3,249.50
Concrete-Rectangular-Column: 2	2.04	$909.87	$2,425.00	$4,947.00
Rectangular-Column: F20 Footing	0.3	$133.80	$2,425.00	$727.50
Rectangular-Column: F20 Footing	0.3	$133.80	$2,425.00	$727.50
Rectangular-Column: F20 Footing	0.3	$133.80	$2,425.00	$727.50
Total (CY)	43.85	$19,557.75		$106,336.25

Floor Schedule	cost per CY of Concrete		$446.01	
Family and Type	Volume (CY)	total cost	RS Means Cost	
			Cost per CY	Total Cost
Floor: 8" Concrete	18.45	$8,228.97	$800.00	$14,760.00
Floor: 3 1/2" Concrete	46.38	$20,686.17	$700.00	$32,466.00
Floor: 3 1/2" Concrete	355.79	$158,687.60	$700.00	$249,053.00

Floor: 3 1/2" Concrete	415.57	$185,350.37	$700.00	$290,899.00
Floor: 3 1/2" Concrete	45.68	$20,373.96	$700.00	$31,976.00
	Total	$393,327.07		$619,154.00

Appendix M: Structural Steel Baseline Costs

Structural Column Schedule						
Family and Type	Length (ft)	W (lb/ft)	Weight	Cost per unit	Total Cost	Cost per Pound
W-Wide Flange-Column: W12X120	50.33	120	6039.6	$189.00	$9,512.37	$79.27
W-Wide Flange-Column: W12X106	50.33	106	5334.98	$160.00	$8,052.80	$75.97
W-Wide Flange-Column: W12X106	50.33	106	5334.98	$160.00	$8,052.80	$75.97
W-Wide Flange-Column: W12X106	50.33	106	5334.98	$160.00	$8,052.80	$75.97
W-Wide Flange-Column: W12X106	50.33	106	5334.98	$160.00	$8,052.80	$75.97
W-Wide Flange-Column: W12X106	50.33	106	5334.98	$160.00	$8,052.80	$75.97
W-Wide Flange-Column: W12X106	50.33	106	5334.98	$160.00	$8,052.80	$75.97
W-Wide Flange-Column: W12X106	59.17	106	6272.02	$160.00	$9,467.20	$89.31
W-Wide Flange-Column: W12X106	59.17	106	6272.02	$160.00	$9,467.20	$89.31
W-Wide Flange-Column: W12X120	59.17	120	7100.4	$189.00	$11,183.13	$93.19
W-Wide Flange-Column: W12X87	36.46	87	3172.02	$138.00	$5,031.48	$57.83
W-Wide Flange-Column: W12X87	36.46	87	3172.02	$138.00	$5,031.48	$57.83
W-Wide Flange-Column: W12X87	59.17	87	5147.79	$138.00	$8,165.46	$93.86
W-Wide Flange-Column: W12X87	50.33	87	4378.71	$138.00	$6,945.54	$79.83
W-Wide Flange-Column: W12X87	50.33	87	4378.71	$138.00	$6,945.54	$79.83
W-Wide Flange-Column: W12X40	10.46	40	418.4	$80.00	$836.80	$20.92
W-Wide Flange-Column: W12X87	51.83	87	4509.21	$138.00	$7,152.54	$82.21
W-Wide Flange-Column: W12X87	50.83	87	4422.21	$138.00	$7,014.54	$80.63
W-Wide Flange-Column: W12X106	38.08	106	4036.48	$160.00	$6,092.80	$57.48
W-Wide Flange-Column: W12X87	38.88	87	3382.56	$138.00	$5,365.44	$61.67
W-Wide Flange-Column: W12X106	38.88	106	4121.28	$160.00	$6,220.80	$58.69
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	30.54	106	3237.24	$160.00	$4,886.40	$46.10
W-Wide Flange-Column: W12X106	39.38	106	4174.28	$160.00	$6,300.80	$59.44
W-Wide Flange-Column: W12X106	39.38	106	4174.28	$160.00	$6,300.80	$59.44
W-Wide Flange-Column: W12X106	39.38	106	4174.28	$160.00	$6,300.80	$59.44
W-Wide Flange-Column: W12X106	39.92	106	4231.52	$160.00	$6,387.20	$60.26
W-Wide Flange-Column: W12X87	17.21	87	1497.27	$138.00	$2,374.98	$27.30
W-Wide Flange-Column: W12X96	39.92	96	3832.32	$150.00	$5,988.00	$62.38

W-Wide Flange-Column: W12X96	31.08	96	2983.68	$150.00	$4,662.00	$48.56
W-Wide Flange-Column: W12X40	31.08	40	1243.2	$80.00	$2,486.40	$62.16
W-Wide Flange-Column: W12X40	31.08	40	1243.2	$80.00	$2,486.40	$62.16
W-Wide Flange-Column: W12X87	31.08	87	2703.96	$138.00	$4,289.04	$49.30
W-Wide Flange-Column: W12X87	31.08	87	2703.96	$138.00	$4,289.04	$49.30
W-Wide Flange-Column: W12X96	31.08	96	2983.68	$150.00	$4,662.00	$48.56
W-Wide Flange-Column: W12X96	31.08	96	2983.68	$150.00	$4,662.00	$48.56
HSS-Column: HSS5X5X5/16	13.88	19	263.72	$12.80	$3,375.62	$177.66
HSS: HSS5X5X5/16	8.83	19	167.77	$12.80	$2,147.46	$113.02
HSS: HSS5X5X5/16	8.83	19	167.77	$12.80	$2,147.46	$113.02
HSS: HSS5X5X5/16	8.83	19	167.77	$12.80	$2,147.46	$113.02
HSS: HSS5X5X5/16	8.83	19	167.77	$12.80	$2,147.46	$113.02
HSS: HSS5X5X5/16	13.88	19	263.72	$12.80	$3,375.62	$177.66
Total (lb)			164859.06		$268,370.84	

Structural Framing Schedule

Family and Type	Length (ft)	W (lb/ft)	Weight (lb)	Cost per unit	Total Cost	Cost per Pound.
W-Wide Flange: W14X22	15.69	22	345.18	$46.00	$721.74	$32.81
W-Wide Flange: W14X22	15.69	22	345.18	$46.00	$721.74	$32.81
W-Wide Flange: W14X22	15.48	22	340.56	$46.00	$712.08	$32.37
W-Wide Flange: W14X22	15.48	22	340.56	$46.00	$712.08	$32.37
W-Wide Flange: W16X26	21.44	26	557.44	$46.00	$986.24	$37.93
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	14	26	364	$46.00	$644.00	$24.77
W-Wide Flange: W16X26	22.01	26	572.26	$46.00	$1,012.46	$38.94
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W18X35	21.44	35	750.4	$62.00	$1,329.28	$37.98
W-Wide Flange: W14X22	13	22	286	$46.00	$598.00	$27.18
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	15.69	40	627.6	$69.50	$1,090.46	$27.26
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W21X44	21.43	44	942.92	$74.50	$1,596.54	$36.28
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W24X62	28.91	62	1792.42	$102.00	$2,948.82	$47.56

W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	29.33	62	1818.46	$102.00	$2,991.66	$48.25
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W21X44	28.94	44	1273.36	$74.50	$2,156.03	$49.00
W-Wide Flange: W21X44	28.96	44	1274.24	$74.50	$2,157.52	$49.03
W-Wide Flange: W18X40	18.96	40	758.4	$69.50	$1,317.72	$32.94
W-Wide Flange: W8X31	17.78	31	551.18	$58.50	$1,040.13	$33.55
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X35	33	35	1155	$62.00	$2,046.00	$58.46
W-Wide Flange: W16X26	19.17	26	498.42	$46.00	$881.82	$33.92
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$55.74
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W18X40	31	40	1240	$69.50	$2,154.50	$53.86
W-Wide Flange: W21X44	29.46	44	1296.24	$170.00	$5,008.20	$113.82
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$119.50
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$119.50
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$119.50
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$119.50
W-Wide Flange: W21X44	32.46	44	1428.24	$170.00	$5,518.20	$125.41
W-Wide Flange: W18X40	17.78	40	711.2	$62.00	$1,102.36	$27.56
W-Wide Flange: W18X40	18.96	40	758.4	$62.00	$1,175.52	$29.39
W-Wide Flange: W18X40	28.96	40	1158.4	$62.00	$1,795.52	$44.89

W-Wide Flange: W18X40	28.94	40	1157.6	$62.00	$1,794.28	$44.86
W-Wide Flange: W18X40	32.46	40	1298.4	$62.00	$2,012.52	$50.31
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66	$47.94
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66	$47.94
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66	$47.94
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66	$47.94
W-Wide Flange: W18X40	29.46	40	1178.4	$62.00	$1,826.52	$45.66
W-Wide Flange: W16X26	17.21	26	447.46	$46.00	$791.66	$30.45
W-Wide Flange: W16X26	14.64	26	380.64	$46.00	$673.44	$25.90
W-Wide Flange: W16X26	16.13	26	419.38	$46.00	$741.98	$28.54
W-Wide Flange: W18X40	28.96	40	1158.4	$62.00	$1,795.52	$44.89
W-Wide Flange: W16X26	7.78	26	202.28	$46.00	$357.88	$13.76
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07	$47.62
W-Wide Flange: W18X40	15.28	40	611.2	$69.50	$1,061.96	$26.55
W-Wide Flange: W21X50	21.45	50	1072.5	$83.50	$1,791.08	$35.82
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07	$47.62
W-Wide Flange: W24X55	28.93	55	1591.15	$90.50	$2,618.17	$47.60
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W21X50	21.43	50	1071.5	$83.50	$1,789.41	$35.79
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W24X62	28.91	62	1792.42	$102.00	$2,948.82	$47.56
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	29.45	62	1825.9	$102.00	$3,003.90	$48.45
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$48.47
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62

W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$55.74
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$55.74
HSS: HSS16X8X5/16	19.09	48.9	933.501	$70.40	$65,718.47	$1,343.94
HSS: HSS16X8X5/16	30.93	48.9	1512.477	$70.40	$106,478.38	$2,177.47
HSS: HSS16X8X5/16	29.46	48.9	1440.594	$70.40	$101,417.82	$2,073.98
W-Wide Flange: W24X55	31	55	1705	$90.50	$2,805.50	$51.01
W-Wide Flange: W21X44	29	44	1276	$74.50	$2,160.50	$49.10
W-Wide Flange: W16X26	7.78	26	202.28	$46.00	$357.88	$13.76
W-Wide Flange: W24X55	31	55	1705	$90.50	$2,805.50	$51.01
W-Wide Flange: W24X68	38.83	68	2640.44	$111.00	$4,310.13	$63.38
W-Wide Flange: W18X35	28.96	35	1013.6	$62.00	$1,795.52	$51.30
W-Wide Flange: W16X26	16.13	26	419.38	$46.00	$741.98	$28.54
W-Wide Flange: W16X26	14.64	26	380.64	$46.00	$673.44	$25.90
W-Wide Flange: W16X26	17.21	26	447.46	$46.00	$791.66	$30.45
W-Wide Flange: W18X40	29.46	40	1178.4	$69.50	$2,047.47	$51.19
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$53.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$53.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$53.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$53.74
W-Wide Flange: W18X40	32.46	40	1298.4	$69.50	$2,255.97	$56.40
W-Wide Flange: W21X44	28.94	44	1273.36	$74.50	$2,156.03	$49.00
W-Wide Flange: W21X44	28.96	44	1274.24	$74.50	$2,157.52	$49.03
W-Wide Flange: W16X31	18.96	31	587.76	$54.00	$1,023.84	$33.03
W-Wide Flange: W16X31	17.78	31	551.18	$54.00	$960.12	$30.97
W-Wide Flange: W21X55	32.46	55	1785.3	$83.50	$2,710.41	$49.28
W-Wide Flange: W21X50	30.93	50	1546.5	$83.50	$2,582.66	$51.65
W-Wide Flange: W21X44	30.93	44	1360.92	$74.50	$2,304.29	$52.37
W-Wide Flange: W12X19	11.42	19	216.98	$40.50	$462.51	$24.34
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07	$47.62

W-Wide Flange: W21X48	28.93	48	1388.64	$83.50	$2,415.66	$50.33
W-Wide Flange: W14X22	31	22	682	$46.00	$1,426.00	$64.82
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$62.73
W-Wide Flange: W18X35	30	35	1050	$62.00	$1,860.00	$53.14
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$56.69
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$56.69
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$55.60
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$55.60
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$36.30
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00	$54.18
W-Wide Flange: W14X22	32	22	704	$74.50	$2,384.00	$108.36
W-Wide Flange: W14X22	32	22	704	$74.50	$2,384.00	$108.36
W-Wide Flange: W14X22	32	22	704	$74.50	$2,384.00	$108.36
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08	$37.25
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08	$37.25
W-Wide Flange: W16X31	33	31	1023	$54.00	$1,782.00	$57.48
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$56.69
W-Wide Flange: W21X55	32	55	1760	$102.00	$3,264.00	$59.35
W-Wide Flange: W21X48	29.45	48	1413.6	$83.50	$2,459.08	$51.23
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$51.25
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$51.25
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$51.25
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$51.25
W-Wide Flange: W21X48	29	48	1392	$83.50	$2,421.50	$50.45
W-Wide Flange: W21X48	28.93	48	1388.64	$83.50	$2,415.66	$50.33
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$47.59
W-Wide Flange: W27X84	28.93	84	2430.12	$134.00	$3,876.62	$46.15
W-Wide Flange: W24X68	28.91	68	1965.88	$111.00	$3,209.01	$47.19
W-Wide Flange: W18X40	38.42	40	1536.8	$69.50	$2,670.19	$66.75
W-Wide Flange: W14X22	8.79	22	193.38	$46.00	$404.34	$18.38
W-Wide Flange: W14X22	8.79	22	193.38	$46.00	$404.34	$18.38
W-Wide Flange: W21X44	37.77	44	1661.88	$74.50	$2,813.87	$63.95
W-Wide Flange: W21X44	30	44	1320	$74.50	$2,235.00	$50.80
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00	$54.18
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00	$54.18
W-Wide Flange: W21X48	30	48	1440	$83.50	$2,505.00	$52.19
W-Wide Flange: W24X55	30.93	55	1701.15	$102.00	$3,154.86	$57.36
W-Wide Flange: W24X55	30.93	55	1701.15	$102.00	$3,154.86	$57.36

W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$27.47
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08	$37.25
W-Wide Flange: W14X22	9.79	22	215.38	$46.00	$450.34	$20.47
W-Wide Flange: W14X22	21.58	22	474.76	$46.00	$992.68	$45.12
W-Wide Flange: W14X22	9.25	22	203.5	$46.00	$425.50	$19.34
W-Wide Flange: W18X40	38.29	40	1531.6	$69.50	$2,661.16	$66.53
W-Wide Flange: W18X40	38.3	40	1532	$69.50	$2,661.85	$66.55
W-Wide Flange: W18X40	30	40	1200	$69.50	$2,085.00	$52.13
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W12X26	32	26	832	$46.50	$1,488.00	$57.23
W-Wide Flange: W16X26	32	26	832	$46.50	$1,488.00	$57.23
W-Wide Flange: W16X26	32	26	832	$46.50	$1,488.00	$57.23
W-Wide Flange: W12X19	12.6	19	239.4	$40.50	$510.30	$26.86
W-Wide Flange: W12X19	12.8	19	243.2	$40.50	$518.40	$27.28
W-Wide Flange: W12X19	14	19	266	$40.50	$567.00	$29.84
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75	$15.99
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W8X24	20.03	24	480.72	$48.00	$961.44	$40.06
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	31.17	26	810.42	$46.00	$1,433.82	$55.15
W-Wide Flange: W16X26	31.17	26	810.42	$46.00	$1,433.82	$55.15
W-Wide Flange: W16X26	31.17	26	810.42	$46.00	$1,433.82	$55.15
W-Wide Flange: W16X26	31.17	26	810.42	$46.00	$1,433.82	$55.15
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62

W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$55.74
W-Wide Flange: W12X19	26.5	19	503.5	$40.50	$1,073.25	$56.49
W-Wide Flange: W16X26	15	26	390	$46.00	$690.00	$26.54
W-Wide Flange: W12X19	11.33	19	215.27	$40.50	$458.87	$24.15
W-Wide Flange: W14X22	20.67	22	454.74	$46.00	$950.82	$43.22
W-Wide Flange: W14X22	31.17	22	685.74	$46.00	$1,433.82	$65.17
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	22.67	22	498.74	$46.00	$1,042.82	$47.40
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W14X22	13	22	286	$46.00	$598.00	$27.18
W-Wide Flange: W8X24	20	24	480	$48.00	$960.00	$40.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W12X19	22.5	19	427.5	$40.50	$911.25	$47.96
W-Wide Flange: W8X15	14	15	210	$33.00	$462.00	$30.80
W-Wide Flange: W8X15	14	15	210	$33.00	$462.00	$30.80
W-Wide Flange: W8X15	9.15	15	137.25	$33.00	$301.95	$20.13
W-Wide Flange: W8X15	8.89	15	133.35	$33.00	$293.37	$19.56
W-Wide Flange: W8X15	8.63	15	129.45	$33.00	$284.79	$18.99
W-Wide Flange: W8X15	9.42	15	141.3	$33.00	$310.86	$20.72
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10.17	17	172.89	$44.00	$447.48	$26.32
W-Wide Flange: W10X17	10.17	17	172.89	$44.00	$447.48	$26.32
W-Wide Flange: W16X26	10.17	26	264.42	$46.00	$467.82	$17.99
W-Wide Flange: W14X22	20.02	22	440.44	$46.00	$920.92	$41.86
W-Wide Flange: W10X17	9.05	17	153.85	$44.00	$398.20	$23.42
W-Wide Flange: W10X17	9.26	17	157.42	$44.00	$407.44	$23.97
W-Wide Flange: W10X17	9.46	17	160.82	$44.00	$416.24	$24.48
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66

W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$10.66
W-Wide Flange: W8X15	5	15	75	$33.00	$165.00	$11.00
W-Wide Flange: W8X15	5	15	75	$33.00	$165.00	$11.00
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W10X17	9.58	17	162.86	$44.00	$421.52	$24.80
W-Wide Flange: W8X15	2.67	15	40.05	$33.00	$88.11	$5.87
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51	$21.76
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75	$15.99
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75	$15.99
W-Wide Flange: W12X19	16.71	19	317.49	$40.50	$676.76	$35.62
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$55.74
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$55.74
W-Wide Flange: W12X19	9.88	19	187.72	$40.50	$400.14	$21.06
W-Wide Flange: W8X15	9.88	15	148.2	$33.00	$326.04	$21.74
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W12X19	9.88	19	187.72	$40.50	$400.14	$21.06
W-Wide Flange: W12X19	9.88	19	187.72	$40.50	$400.14	$21.06
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W12X19	9.88	19	187.72	$46.00	$454.48	$23.92
W-Wide Flange: W12X19	9.88	19	187.72	$46.00	$454.48	$23.92
W-Wide Flange: W10X17	9.58	17	162.86	$44.00	$421.52	$24.80
W-Wide Flange: W8X15	2.67	15	40.05	$33.00	$88.11	$5.87
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W12X19	9.42	19	178.98	$40.50	$381.51	$20.08
W-Wide Flange: W12X19	9.42	19	178.98	$40.50	$381.51	$20.08
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00

W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$22.00
W-Wide Flange: W14X22	28.77	22	632.94	$46.00	$1,323.42	$60.16
W-Wide Flange: W14X22	23.45	22	515.9	$46.00	$1,078.70	$49.03
W-Wide Flange: W8X15	11.95	15	179.25	$33.00	$394.35	$26.29
W-Wide Flange: W8X15	6.97	15	104.55	$33.00	$230.01	$15.33
W-Wide Flange: W12X19	4.57	19	86.83	$40.50	$185.09	$9.74
W-Wide Flange: W12X19	7.81	19	148.39	$40.50	$316.31	$16.65
W-Wide Flange: W12X19	9.01	19	171.19	$40.50	$364.91	$19.21
W-Wide Flange: W14X22	22.85	22	502.7	$46.00	$1,051.10	$47.78
W-Wide Flange: W12X19	14.48	19	275.12	$40.50	$586.44	$30.87
W-Wide Flange: W12X19	13.16	19	250.04	$40.50	$532.98	$28.05
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$55.74

W-Wide Flange: W16X26	13.67	26	355.42	$46.00	$628.82	$24.19
W-Wide Flange: W14X22	20.67	22	454.74	$46.00	$950.82	$43.22
W-Wide Flange: W12X19	11.33	19	215.27	$40.50	$458.87	$24.15
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61	$17.97
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61	$17.97
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61	$17.97
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$17.42
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$17.42
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$17.42
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$17.42
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$17.42
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$17.42
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$17.42
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$11.02
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W10X17	6.83	17	116.11	$44.00	$300.52	$17.68
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W10X17	8.83	17	150.11	$44.00	$388.52	$22.85
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$25.88
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$11.02
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$11.02
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$11.02
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$11.02
W-Wide Flange: W12X19	4.11	19	78.09	$40.50	$166.46	$8.76
W-Wide Flange: W12X19	10	19	190	$40.50	$405.00	$21.32
W-Wide Flange: W12X19	10	19	190	$40.50	$405.00	$21.32
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75	$15.99
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75	$15.99
W-Wide Flange: W12X19	16.71	19	317.49	$40.50	$676.76	$35.62
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$11.02
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00	$46.00
W-Wide Flange: W16X26	22	26	572	$46.00	$1,012.00	$38.92
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00	$46.00
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00	$46.00
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00	$46.00

W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00	$46.00
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$54.85
W-Wide Flange: W14X22	31	22	682	$46.00	$1,426.00	$64.82
W-Wide Flange: W14X22	31	22	682	$46.00	$1,426.00	$64.82
W-Wide Flange: W14X22	31	22	682	$46.00	$1,426.00	$64.82
W-Wide Flange: W10X12	6	12	72	$28.50	$171.00	$14.25
W-Wide Flange: W10X12	10	12	120	$28.50	$285.00	$23.75
W-Wide Flange: W14X22	29.71	22	653.62	$46.00	$1,366.66	$62.12
W-Wide Flange: W14X22	28.3	22	622.6	$46.00	$1,301.80	$59.17
W-Wide Flange: W12X19	25.49	19	484.31	$40.50	$1,032.35	$54.33
W-Wide Flange: W12X19	19.36	19	367.84	$40.50	$784.08	$41.27
W-Wide Flange: W12X14	7.95	14	111.3	$31.00	$246.45	$17.60
W-Wide Flange: W12X14	4.73	14	66.22	$31.00	$146.63	$10.47
W-Wide Flange: W12X14	2.35	14	32.9	$31.00	$72.85	$5.20
W-Wide Flange: W12X14	4.93	14	69.02	$31.00	$152.83	$10.92
W-Wide Flange: W12X14	3.72	14	52.08	$31.00	$115.32	$8.24
W-Wide Flange: W12X14	10	14	140	$31.00	$310.00	$22.14
W-Wide Flange: W12X14	10	14	140	$31.00	$310.00	$22.14
W-Wide Flange: W12X14	8	14	112	$31.00	$248.00	$17.71
W-Wide Flange: W10X12	8	12	96	$28.50	$228.00	$19.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$53.08
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$62.73
W-Wide Flange: W12X14	6.67	14	93.38	$31.00	$206.77	$14.77
W-Wide Flange: W14X22	23	22	506	$46.00	$1,058.00	$48.09
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$62.73
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$62.73
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$62.73
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$62.73
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91

W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$13.29
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91

W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$58.38
W-Wide Flange: W16X26	22.85	26	594.1	$46.00	$1,051.10	$40.43
W-Wide Flange: W12X14	17.19	14	240.66	$31.00	$532.89	$38.06
W-Wide Flange: W12X14	18.18	14	254.52	$31.00	$563.58	$40.26
W-Wide Flange: W12X14	19.17	14	268.38	$31.00	$594.27	$42.45
W-Wide Flange: W12X14	14.81	14	207.34	$31.00	$459.11	$32.79
W-Wide Flange: W12X14	13.82	14	193.48	$31.00	$428.42	$30.60
W-Wide Flange: W12X14	12.83	14	179.62	$31.00	$397.73	$28.41
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$66.91
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$55.60
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$55.60
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$55.60
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$55.60
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$56.62
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$5.36
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$5.36
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$5.36
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$5.36
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$5.36
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$5.36
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$16.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$16.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$16.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$16.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$16.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$16.23
W-Wide Flange: W21X48	32	48	1536	$83.50	$2,672.00	$55.67
W-Wide Flange: W12X14	10.33	14	144.62	$31.00	$320.23	$22.87
W-Wide Flange: W12X14	10.33	14	144.62	$31.00	$320.23	$22.87
W-Wide Flange: W12X14	13.5	14	189	$31.00	$418.50	$29.89
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$8.86
W-Wide Flange: W6X25	10.33	25	258.25	$41.00	$423.53	$16.94
W-Wide Flange: W12X14	5.79	14	81.06	$31.00	$179.49	$12.82

W-Wide Flange: W12X14	5.79	14	81.06	$31.00	$179.49	$12.82
W-Wide Flange: W12X14	6.92	14	96.88	$31.00	$214.52	$15.32
W-Wide Flange: W8X10	6.33	10	63.3	$25.50	$161.42	$16.14
W-Wide Flange: W12X19	9.46	19	179.74	$40.50	$383.13	$20.16
W-Wide Flange: W12X19	11.96	19	227.24	$40.50	$484.38	$25.49
W-Wide Flange: W6X25	9.88	25	247	$25.50	$251.94	$10.08
W-Wide Flange: W12X14	6.08	14	85.12	$31.00	$188.48	$13.46
W-Wide Flange: W12X14	6.08	14	85.12	$31.00	$188.48	$13.46
W-Wide Flange: W10X12	5.88	12	70.56	$28.50	$167.58	$13.97
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$55.60
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$56.69
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$8.86
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$8.86
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$8.86
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$8.86
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$8.86
W-Wide Flange: W18X35	33	35	1155	$62.00	$2,046.00	$58.46
W-Wide Flange: W18X35	33	35	1155	$62.00	$2,046.00	$58.46
W-Wide Flange: W18X40	33	40	1320	$69.50	$2,293.50	$57.34
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$10.43
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$10.43
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$10.43
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$10.43
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$10.43
W-Wide Flange: W8X10	10	10	100	$25.50	$255.00	$25.50
W-Wide Flange: W8X10	10	10	100	$25.50	$255.00	$25.50
W-Wide Flange: W8X10	10	10	100	$25.50	$255.00	$25.50
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$67.47
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$14.17
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$14.17
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$14.17
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$14.17

W-Wide Flange: W16X31	38.83	31	1203.73	$54.00	$2,096.82	$67.64
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50	$9.96
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50	$9.96
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50	$9.96
HSS: HSS6X6X3/8	16.09	27.4	440.866	$22.10	$9,743.14	$355.59
HSS: HSS6X6X3/8	16.09	27.4	440.866	$22.10	$9,743.14	$355.59
HSS: HSS6X6X3/8	17.15	27.4	469.91	$22.10	$10,385.01	$379.02
HSS: HSS6X6X3/8	17.15	27.4	469.91	$22.10	$10,385.01	$379.02
HSS: HSS5X5X3/8	17.82	22.3	397.386	$14.90	$5,921.05	$265.52
HSS: HSS5X5X3/8	17.82	22.3	397.386	$14.90	$5,921.05	$265.52
HSS: HSS5X5X3/8	16.99	22.3	378.877	$14.90	$5,645.27	$253.15
HSS: HSS5X5X3/8	16.99	22.3	378.877	$14.90	$5,645.27	$253.15
Total (lb)			396092.67		$1,056,755.74	

Floor Schedule

Family and Type	Area (SF)	Volume (CY)	cost		total cost
Floor: 1 1/2" Metal Roof Deck	15464	71.59	2.31	per sf	$35,721.61
Floor: 1 1/2" Metal Roof Deck	4220	19.54	2.31	per sf	$0.00
					$1,056,755.74

Appendix N: Open-Web Bar Joist Steel Framing Costs

Structural Framing Schedule

Family and Type	Length (ft)	W (lb/ft)	Weight (lb)	Cost per foot	Total Cost
I-Beams					
W-Wide Flange: W14X22	15.69	22	345.18	46.00	721.74
W-Wide Flange: W14X22	15.69	22	345.18	46.00	721.74
W-Wide Flange: W14X22	15.48	22	340.56	46.00	712.08
W-Wide Flange: W14X22	15.48	22	340.56	46.00	712.08
W-Wide Flange: W16X26	21.44	26	557.44	46.00	986.24
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	14	26	364	46.00	644.00
W-Wide Flange: W16X26	22.01	26	572.26	46.00	1012.46
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W18X35	21.44	35	750.4	62.00	1329.28
W-Wide Flange: W14X22	13	22	286	46.00	598.00
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	15.69	40	627.6	69.50	1090.46
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W21X44	21.43	44	942.92	74.50	1596.54
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W24X62	28.91	62	1792.42	102.00	2948.82
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	29.33	62	1818.46	102.00	2991.66
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W21X44	28.94	44	1273.36	74.50	2156.03
W-Wide Flange: W21X44	28.96	44	1274.24	74.50	2157.52
W-Wide Flange: W18X40	18.96	40	758.4	69.50	1317.72
W-Wide Flange: W8X31	17.78	31	551.18	58.50	1040.13
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80

W-Wide Flange: W18X35	33	35	1155	62.00	2046.00
W-Wide Flange: W16X26	19.17	26	498.42	46.00	881.82
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X31	32	31	992	54.00	1728.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W18X40	31	40	1240	69.50	2154.50
W-Wide Flange: W21X44	29.46	44	1296.24	170.00	5008.20
W-Wide Flange: W21X44	30.93	44	1360.92	170.00	5258.10
W-Wide Flange: W21X44	30.93	44	1360.92	170.00	5258.10
W-Wide Flange: W21X44	30.93	44	1360.92	170.00	5258.10
W-Wide Flange: W21X44	30.93	44	1360.92	170.00	5258.10
W-Wide Flange: W21X44	32.46	44	1428.24	170.00	5518.20
W-Wide Flange: W18X40	17.78	40	711.2	62.00	1102.36
W-Wide Flange: W18X40	18.96	40	758.4	62.00	1175.52
W-Wide Flange: W18X40	28.96	40	1158.4	62.00	1795.52
W-Wide Flange: W18X40	28.94	40	1157.6	62.00	1794.28
W-Wide Flange: W18X40	32.46	40	1298.4	62.00	2012.52
W-Wide Flange: W18X40	30.93	40	1237.2	62.00	1917.66
W-Wide Flange: W18X40	30.93	40	1237.2	62.00	1917.66
W-Wide Flange: W18X40	30.93	40	1237.2	62.00	1917.66
W-Wide Flange: W18X40	30.93	40	1237.2	62.00	1917.66
W-Wide Flange: W18X40	29.46	40	1178.4	62.00	1826.52
W-Wide Flange: W16X26	17.21	26	447.46	46.00	791.66
W-Wide Flange: W16X26	14.64	26	380.64	46.00	673.44
W-Wide Flange: W16X26	16.13	26	419.38	46.00	741.98
W-Wide Flange: W18X40	28.96	40	1158.4	62.00	1795.52
W-Wide Flange: W16X26	7.78	26	202.28	46.00	357.88
W-Wide Flange: W24X55	28.94	55	1591.7	90.50	2619.07
W-Wide Flange: W18X40	15.28	40	611.2	69.50	1061.96

W-Wide Flange: W21X50	21.45	50	1072.5	83.50	1791.08
W-Wide Flange: W24X55	28.94	55	1591.7	90.50	2619.07
W-Wide Flange: W24X55	28.93	55	1591.15	90.50	2618.17
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W21X50	21.43	50	1071.5	83.50	1789.41
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W24X62	28.91	62	1792.42	102.00	2948.82
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	29.45	62	1825.9	102.00	3003.90
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W24X62	29.46	62	1826.52	102.00	3004.92
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00

W-Wide Flange: W16X31	32	31	992	54.00	1728.00
W-Wide Flange: W16X31	32	31	992	54.00	1728.00
HSS16X8X5/16	19.09	48.9	933.501	70.40	65718.47
HSS16X8X5/16	30.93	48.9	1512.477	70.40	106478.38
HSS16X8X5/16	29.46	48.9	1440.594	70.40	101417.82
W-Wide Flange: W24X55	31	55	1705	90.50	2805.50
W-Wide Flange: W21X44	29	44	1276	74.50	2160.50
W-Wide Flange: W16X26	7.78	26	202.28	46.00	357.88
W-Wide Flange: W24X55	31	55	1705	90.50	2805.50
W-Wide Flange: W24X68	38.83	68	2640.44	111.00	4310.13
W-Wide Flange: W18X35	28.96	35	1013.6	62.00	1795.52
W-Wide Flange: W16X26	16.13	26	419.38	46.00	741.98
W-Wide Flange: W16X26	14.64	26	380.64	46.00	673.44
W-Wide Flange: W16X26	17.21	26	447.46	46.00	791.66
W-Wide Flange: W18X40	29.46	40	1178.4	69.50	2047.47
W-Wide Flange: W18X40	30.93	40	1237.2	69.50	2149.64
W-Wide Flange: W18X40	30.93	40	1237.2	69.50	2149.64
W-Wide Flange: W18X40	30.93	40	1237.2	69.50	2149.64
W-Wide Flange: W18X40	30.93	40	1237.2	69.50	2149.64
W-Wide Flange: W18X40	32.46	40	1298.4	69.50	2255.97
W-Wide Flange: W21X44	28.94	44	1273.36	74.50	2156.03
W-Wide Flange: W21X44	28.96	44	1274.24	74.50	2157.52
W-Wide Flange: W16X31	18.96	31	587.76	54.00	1023.84
W-Wide Flange: W16X31	17.78	31	551.18	54.00	960.12
W-Wide Flange: W21X55	32.46	55	1785.3	83.50	2710.41
W-Wide Flange: W21X50	30.93	50	1546.5	83.50	2582.66
W-Wide Flange: W21X44	30.93	44	1360.92	74.50	2304.29
W-Wide Flange: W12X19	11.42	19	216.98	40.50	462.51
W-Wide Flange: W24X55	28.94	55	1591.7	90.50	2619.07
W-Wide Flange: W21X48	28.93	48	1388.64	83.50	2415.66
W-Wide Flange: W14X22	31	22	682	46.00	1426.00
W-Wide Flange: W14X22	30	22	660	46.00	1380.00
W-Wide Flange: W18X35	30	35	1050	62.00	1860.00
W-Wide Flange: W18X35	32	35	1120	62.00	1984.00
W-Wide Flange: W18X35	32	35	1120	62.00	1984.00
W-Wide Flange: W18X40	32	40	1280	69.50	2224.00
W-Wide Flange: W18X40	32	40	1280	69.50	2224.00
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W21X44	21.44	44	943.36	74.50	1597.28
W-Wide Flange: W21X44	32	44	1408	74.50	2384.00
W-Wide Flange: W14X22	32	22	704	74.50	2384.00
W-Wide Flange: W14X22	32	22	704	74.50	2384.00
W-Wide Flange: W14X22	32	22	704	74.50	2384.00

W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W18X40	21.44	40	857.6	69.50	1490.08
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	21.44	40	857.6	69.50	1490.08
W-Wide Flange: W16X31	33	31	1023	54.00	1782.00
W-Wide Flange: W18X35	32	35	1120	62.00	1984.00
W-Wide Flange: W21X55	32	55	1760	102.00	3264.00
W-Wide Flange: W21X48	29.45	48	1413.6	83.50	2459.08
W-Wide Flange: W21X48	29.46	48	1414.08	83.50	2459.91
W-Wide Flange: W21X48	29.46	48	1414.08	83.50	2459.91
W-Wide Flange: W21X48	29.46	48	1414.08	83.50	2459.91
W-Wide Flange: W21X48	29.46	48	1414.08	83.50	2459.91
W-Wide Flange: W21X48	29	48	1392	83.50	2421.50
W-Wide Flange: W21X48	28.93	48	1388.64	83.50	2415.66
W-Wide Flange: W24X62	28.93	62	1793.66	102.00	2950.86
W-Wide Flange: W27X84	28.93	84	2430.12	134.00	3876.62
W-Wide Flange: W24X68	28.91	68	1965.88	111.00	3209.01
W-Wide Flange: W18X40	38.42	40	1536.8	69.50	2670.19
W-Wide Flange: W14X22	8.79	22	193.38	46.00	404.34
W-Wide Flange: W14X22	8.79	22	193.38	46.00	404.34
W-Wide Flange: W21X44	37.77	44	1661.88	74.50	2813.87
W-Wide Flange: W21X44	30	44	1320	74.50	2235.00
W-Wide Flange: W21X44	32	44	1408	74.50	2384.00
W-Wide Flange: W21X44	32	44	1408	74.50	2384.00
W-Wide Flange: W21X48	30	48	1440	83.50	2505.00
W-Wide Flange: W24X55	30.93	55	1701.15	102.00	3154.86
W-Wide Flange: W24X55	30.93	55	1701.15	102.00	3154.86
W-Wide Flange: W18X40	15.81	40	632.4	69.50	1098.80
W-Wide Flange: W18X40	21.44	40	857.6	69.50	1490.08
W-Wide Flange: W14X22	9.79	22	215.38	46.00	450.34
W-Wide Flange: W14X22	21.58	22	474.76	46.00	992.68
W-Wide Flange: W14X22	9.25	22	203.5	46.00	425.50
W-Wide Flange: W18X40	38.29	40	1531.6	69.50	2661.16
W-Wide Flange: W18X40	38.3	40	1532	69.50	2661.85
W-Wide Flange: W18X40	30	40	1200	69.50	2085.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W12X26	32	26	832	46.50	1488.00

W-Wide Flange: W16X26	32	26	832	46.50	1488.00
W-Wide Flange: W16X26	32	26	832	46.50	1488.00
W-Wide Flange: W12X19	12.6	19	239.4	40.50	510.30
W-Wide Flange: W12X19	12.8	19	243.2	40.50	518.40
W-Wide Flange: W12X19	14	19	266	40.50	567.00
W-Wide Flange: W12X19	7.5	19	142.5	40.50	303.75
W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W8X24	20.03	24	480.72	48.00	961.44
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X31	32	31	992	46.00	1472.00
W-Wide Flange: W12X19	26.5	19	503.5	40.50	1073.25
W-Wide Flange: W16X26	15	26	390	46.00	690.00
W-Wide Flange: W12X19	11.33	19	215.27	40.50	458.87
W-Wide Flange: W14X22	20.67	22	454.74	46.00	950.82
W-Wide Flange: W14X22	31.17	22	685.74	46.00	1433.82
W-Wide Flange: W14X22	22.67	22	498.74	46.00	1042.82
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W14X22	13	22	286	46.00	598.00
W-Wide Flange: W8X24	20	24	480	48.00	960.00
W-Wide Flange: W12X19	22.5	19	427.5	40.50	911.25
W-Wide Flange: W8X15	14	15	210	33.00	462.00
W-Wide Flange: W8X15	14	15	210	33.00	462.00
W-Wide Flange: W8X15	9.15	15	137.25	33.00	301.95
W-Wide Flange: W8X15	8.89	15	133.35	33.00	293.37
W-Wide Flange: W8X15	8.63	15	129.45	33.00	284.79
W-Wide Flange: W8X15	9.42	15	141.3	33.00	310.86
W-Wide Flange: W16X26	20	26	520	46.00	920.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	20.33	26	528.58	46.00	935.18
W-Wide Flange: W16X26	10.17	26	264.42	46.00	467.82
W-Wide Flange: W14X22	20.02	22	440.44	46.00	920.92
W-Wide Flange: W10X17	9.05	17	153.85	44.00	398.20
W-Wide Flange: W10X17	9.26	17	157.42	44.00	407.44
W-Wide Flange: W10X17	9.46	17	160.82	44.00	416.24
W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W12X19	5	19	95	40.50	202.50

W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W12X19	5	19	95	40.50	202.50
W-Wide Flange: W8X15	5	15	75	33.00	165.00
W-Wide Flange: W8X15	5	15	75	33.00	165.00
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W10X17	9.58	17	162.86	44.00	421.52
W-Wide Flange: W8X15	2.67	15	40.05	33.00	88.11
W-Wide Flange: W12X19	10.21	19	193.99	40.50	413.51
W-Wide Flange: W12X19	7.5	19	142.5	40.50	303.75
W-Wide Flange: W12X19	7.5	19	142.5	40.50	303.75
W-Wide Flange: W12X19	16.71	19	317.49	40.50	676.76
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X31	32	31	992	54.00	1728.00
W-Wide Flange: W16X31	32	31	992	54.00	1728.00
W-Wide Flange: W12X19	9.88	19	187.72	40.50	400.14
W-Wide Flange: W8X15	9.88	15	148.2	33.00	326.04
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W12X19	9.88	19	187.72	40.50	400.14
W-Wide Flange: W12X19	9.88	19	187.72	40.50	400.14
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W12X19	9.88	19	187.72	46.00	454.48
W-Wide Flange: W12X19	9.88	19	187.72	46.00	454.48
W-Wide Flange: W10X17	9.58	17	162.86	44.00	421.52
W-Wide Flange: W8X15	2.67	15	40.05	33.00	88.11
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W12X19	9.42	19	178.98	40.50	381.51
W-Wide Flange: W12X19	9.42	19	178.98	40.50	381.51
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00

W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W8X15	10	15	150	33.00	330.00
W-Wide Flange: W14X22	28.77	22	632.94	46.00	1323.42
W-Wide Flange: W14X22	23.45	22	515.9	46.00	1078.70
W-Wide Flange: W8X15	11.95	15	179.25	33.00	394.35
W-Wide Flange: W8X15	6.97	15	104.55	33.00	230.01
W-Wide Flange: W12X19	4.57	19	86.83	40.50	185.09
W-Wide Flange: W12X19	7.81	19	148.39	40.50	316.31
W-Wide Flange: W12X19	9.01	19	171.19	40.50	364.91
W-Wide Flange: W14X22	22.85	22	502.7	46.00	1051.10
W-Wide Flange: W12X19	14.48	19	275.12	40.50	586.44
W-Wide Flange: W12X19	13.16	19	250.04	40.50	532.98
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X31	32	31	992	54.00	1728.00
W-Wide Flange: W16X26	13.67	26	355.42	46.00	628.82
W-Wide Flange: W14X22	20.67	22	454.74	46.00	950.82
W-Wide Flange: W12X19	11.33	19	215.27	40.50	458.87
W-Wide Flange: W8X15	8.17	15	122.55	33.00	269.61
W-Wide Flange: W8X15	8.17	15	122.55	33.00	269.61
W-Wide Flange: W8X15	8.17	15	122.55	33.00	269.61
W-Wide Flange: W12X19	8.17	19	155.23	40.50	330.89
W-Wide Flange: W12X19	8.17	19	155.23	40.50	330.89
W-Wide Flange: W12X19	8.17	19	155.23	40.50	330.89
W-Wide Flange: W12X19	8.17	19	155.23	40.50	330.89
W-Wide Flange: W12X19	8.17	19	155.23	40.50	330.89
W-Wide Flange: W12X19	8.17	19	155.23	40.50	330.89
W-Wide Flange: W12X19	8.17	19	155.23	40.50	330.89
W-Wide Flange: W12X19	5.17	19	98.23	40.50	209.39
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W10X17	6.83	17	116.11	44.00	300.52
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W16X26	31	26	806	46.00	1426.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W10X17	8.83	17	150.11	44.00	388.52
W-Wide Flange: W10X17	10	17	170	44.00	440.00
W-Wide Flange: W10X17	10	17	170	44.00	440.00
W-Wide Flange: W10X17	10	17	170	44.00	440.00
W-Wide Flange: W10X17	10	17	170	44.00	440.00

W-Wide Flange: W12X19	5.17	19	98.23	40.50	209.39
W-Wide Flange: W12X19	5.17	19	98.23	40.50	209.39
W-Wide Flange: W12X19	5.17	19	98.23	40.50	209.39
W-Wide Flange: W12X19	5.17	19	98.23	40.50	209.39
W-Wide Flange: W12X19	4.11	19	78.09	40.50	166.46
W-Wide Flange: W12X19	10	19	190	40.50	405.00
W-Wide Flange: W12X19	10	19	190	40.50	405.00
W-Wide Flange: W12X19	7.5	19	142.5	40.50	303.75
W-Wide Flange: W12X19	7.5	19	142.5	40.50	303.75
W-Wide Flange: W12X19	16.71	19	317.49	40.50	676.76
W-Wide Flange: W12X19	5.17	19	98.23	40.50	209.39
W-Wide Flange: W14X22	22	22	484	46.00	1012.00
W-Wide Flange: W16X26	22	26	572	46.00	1012.00
W-Wide Flange: W14X22	22	22	484	46.00	1012.00
W-Wide Flange: W14X22	22	22	484	46.00	1012.00
W-Wide Flange: W14X22	22	22	484	46.00	1012.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W14X22	22	22	484	46.00	1012.00
W-Wide Flange: W14X22	29.71	22	653.62	46.00	1366.66
W-Wide Flange: W14X22	28.3	22	622.6	46.00	1301.80
W-Wide Flange: W12X19	25.49	19	484.31	40.50	1032.35
W-Wide Flange: W12X19	19.36	19	367.84	40.50	784.08
W-Wide Flange: W12X14	7.95	14	111.3	31.00	246.45
W-Wide Flange: W12X14	4.73	14	66.22	31.00	146.63
W-Wide Flange: W12X14	2.35	14	32.9	31.00	72.85
W-Wide Flange: W12X14	4.93	14	69.02	31.00	152.83
W-Wide Flange: W12X14	3.72	14	52.08	31.00	115.32
W-Wide Flange: W12X14	10	14	140	31.00	310.00
W-Wide Flange: W12X14	10	14	140	31.00	310.00
W-Wide Flange: W12X14	8	14	112	31.00	248.00
W-Wide Flange: W10X12	8	12	96	28.50	228.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W14X22	30	22	660	46.00	1380.00
W-Wide Flange: W12X14	6.67	14	93.38	31.00	206.77
W-Wide Flange: W14X22	23	22	506	46.00	1058.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00

W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W12X14	6	14	84	31.00	186.00
W-Wide Flange: W16X26	22.85	26	594.1	46.00	1051.10
W-Wide Flange: W12X14	17.19	14	240.66	31.00	532.89
W-Wide Flange: W12X14	18.18	14	254.52	31.00	563.58
W-Wide Flange: W12X14	19.17	14	268.38	31.00	594.27
W-Wide Flange: W12X14	14.81	14	207.34	31.00	459.11
W-Wide Flange: W12X14	13.82	14	193.48	31.00	428.42
W-Wide Flange: W12X14	12.83	14	179.62	31.00	397.73
W-Wide Flange: W18X40	32	40	1280	69.50	2224.00
W-Wide Flange: W18X40	32	40	1280	69.50	2224.00
W-Wide Flange: W18X40	32	40	1280	69.50	2224.00
W-Wide Flange: W18X40	32	40	1280	69.50	2224.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
W-Wide Flange: W12X14	2.42	14	33.88	31.00	75.02
W-Wide Flange: W12X14	2.42	14	33.88	31.00	75.02
W-Wide Flange: W12X14	2.42	14	33.88	31.00	75.02
W-Wide Flange: W12X14	2.42	14	33.88	31.00	75.02
W-Wide Flange: W12X14	2.42	14	33.88	31.00	75.02
W-Wide Flange: W12X14	2.42	14	33.88	31.00	75.02
W-Wide Flange: W12X14	7.33	14	102.62	31.00	227.23

W-Wide Flange: W12X14	7.33	14	102.62	31.00	227.23
W-Wide Flange: W12X14	7.33	14	102.62	31.00	227.23
W-Wide Flange: W12X14	7.33	14	102.62	31.00	227.23
W-Wide Flange: W12X14	7.33	14	102.62	31.00	227.23
W-Wide Flange: W12X14	7.33	14	102.62	31.00	227.23
W-Wide Flange: W21X48	32	48	1536	83.50	2672.00
W-Wide Flange: W12X14	10.33	14	144.62	31.00	320.23
W-Wide Flange: W12X14	10.33	14	144.62	31.00	320.23
W-Wide Flange: W12X14	13.5	14	189	31.00	418.50
W-Wide Flange: W12X14	4	14	56	31.00	124.00
W-Wide Flange: W6X25	10.33	25	258.25	41.00	423.53
W-Wide Flange: W12X14	5.79	14	81.06	31.00	179.49
W-Wide Flange: W12X14	5.79	14	81.06	31.00	179.49
W-Wide Flange: W12X14	6.92	14	96.88	31.00	214.52
W-Wide Flange: W8X10	6.33	10	63.3	25.50	161.42
W-Wide Flange: W12X19	9.46	19	179.74	40.50	383.13
W-Wide Flange: W12X19	11.96	19	227.24	40.50	484.38
W-Wide Flange: W6X25	9.88	25	247	25.50	251.94
W-Wide Flange: W12X14	6.08	14	85.12	31.00	188.48
W-Wide Flange: W12X14	6.08	14	85.12	31.00	188.48
W-Wide Flange: W10X12	5.88	12	70.56	28.50	167.58
W-Wide Flange: W18X40	32	40	1280	69.50	2224.00
W-Wide Flange: W18X35	32	35	1120	62.00	1984.00
W-Wide Flange: W12X14	4	14	56	31.00	124.00
W-Wide Flange: W12X14	4	14	56	31.00	124.00
W-Wide Flange: W12X14	4	14	56	31.00	124.00
W-Wide Flange: W12X14	4	14	56	31.00	124.00
W-Wide Flange: W12X14	4	14	56	31.00	124.00
W-Wide Flange: W18X35	33	35	1155	62.00	2046.00
W-Wide Flange: W18X35	33	35	1155	62.00	2046.00
W-Wide Flange: W18X40	33	40	1320	69.50	2293.50
W-Wide Flange: W12X14	4.71	14	65.94	31.00	146.01
W-Wide Flange: W12X14	4.71	14	65.94	31.00	146.01
W-Wide Flange: W12X14	4.71	14	65.94	31.00	146.01
W-Wide Flange: W12X14	4.71	14	65.94	31.00	146.01
W-Wide Flange: W12X14	4.71	14	65.94	31.00	146.01
W-Wide Flange: W8X10	10	10	100	25.50	255.00
W-Wide Flange: W8X10	10	10	100	25.50	255.00
W-Wide Flange: W8X10	10	10	100	25.50	255.00
W-Wide Flange: W18X40	38.83	40	1553.2	69.50	2698.69
W-Wide Flange: W18X40	38.83	40	1553.2	69.50	2698.69
W-Wide Flange: W18X40	38.83	40	1553.2	69.50	2698.69
W-Wide Flange: W18X40	38.83	40	1553.2	69.50	2698.69

W-Wide Flange: W12X14	6.4	14	89.6	31.00	198.40
W-Wide Flange: W12X14	6.4	14	89.6	31.00	198.40
W-Wide Flange: W12X14	6.4	14	89.6	31.00	198.40
W-Wide Flange: W12X14	6.4	14	89.6	31.00	198.40
W-Wide Flange: W16X31	38.83	31	1203.73	54.00	2096.82
W-Wide Flange: W12X14	4.5	14	63	31.00	139.50
W-Wide Flange: W12X14	4.5	14	63	31.00	139.50
W-Wide Flange: W12X14	4.5	14	63	31.00	139.50
HSS6X6X3/8	16.09	27.4	440.866	22.10	9743.14
HSS6X6X3/8	16.09	27.4	440.866	22.10	9743.14
HSS6X6X3/8	17.15	27.4	469.91	22.10	10385.01
HSS6X6X3/8	17.15	27.4	469.91	22.10	10385.01
HSS5X5X3/8	17.82	22.3	397.386	14.90	5921.05
HSS5X5X3/8	17.82	22.3	397.386	14.90	5921.05
HSS5X5X3/8	16.99	22.3	378.877	14.90	5645.27
HSS5X5X3/8	16.99	22.3	378.877	14.90	5645.27
W-Wide Flange: W14X22	30	22	660	46.00	1380.00
W-Wide Flange: W14X22	32	22	704	46.00	1472.00
W-Wide Flange: W14X22	32	22	704	46.00	1472.00
W-Wide Flange: W14X22	32	22	704	46.00	1472.00
W-Wide Flange: W14X22	32	22	704	46.00	1472.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X26	30	26	780	46.00	1380.00
W-Wide Flange: W16X26	33	26	858	46.00	1518.00
W-Wide Flange: W16X26	32	26	832	46.00	1472.00
	Total (lb)		315216.19		905073.20

Structural Framing Schedule

Family and Type	W (lb/ft)	Length	Weight	Cost per foot	Total Cost
Bar Joists					
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92

K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 16K2	5.5	16.67	91.685	10.15	169.20
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00

K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50

K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	14.75	455.92
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	11.65	236.84
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	11.65	232.88
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35

K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	30	366	15.35	460.50
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	30	366	15.35	460.50
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	30	366	15.35	460.50
K-Series Bar Joist-Rod Web: 26K9	12.2	30	366	15.35	460.50
K-Series Bar Joist-Rod Web: 24K7	10.1	24	242.4	14.75	354.00
K-Series Bar Joist-Rod Web: 24K7	10.1	24	242.4	14.75	354.00
K-Series Bar Joist-Rod Web: 24K7	10.1	24	242.4	14.75	354.00
K-Series Bar Joist-Rod Web: 24K7	10.1	24	242.4	14.75	354.00
K-Series Bar Joist-Rod Web: 24K7	10.1	24	242.4	14.75	354.00
K-Series Bar Joist-Rod Web: 24K7	10.1	24	242.4	14.75	354.00
K-Series Bar Joist-Rod Web: 24K7	10.1	24	242.4	14.75	354.00
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80

K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	11.95	286.80
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	14.50	435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	12.95	259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	12.95	259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	12.95	259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	12.95	259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	12.95	259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	12.95	259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	12.95	259.00
K-Series Bar Joist-Rod Web: 22K5	8.8	22.5	198	11.60	261.00
K-Series Bar Joist-Rod Web: 22K5	8.8	22.5	198	11.60	261.00
K-Series Bar Joist-Rod Web: 22K5	8.8	22.5	198	11.60	261.00
K-Series Bar Joist-Rod Web: 22K5	8.8	22.5	198	11.60	261.00
K-Series Bar Joist-Rod Web: 22K5	8.8	22.5	198	11.60	261.00
K-Series Bar Joist-Rod Web: 22K5	8.8	22.5	198	11.60	261.00
K-Series Bar Joist-Rod Web: 22K5	8.8	22.5	198	11.60	261.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	14.50	435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	14.50	435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	14.50	435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	14.50	435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	14.50	435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86

K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	14.50	435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	14.50	434.86
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00

K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	10.85	216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	10.85	216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	10.85	216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	10.85	216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	10.85	216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	10.85	217.00
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35

K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	14.75	442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	14.75	442.50
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 22K4	8	22.5	180	11.60	261.00
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35

K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	15.35	460.35
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	14.10	422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	14.10	423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	32	377.6	14.10	451.20
K-Series Bar Joist-Rod Web: 28K7	11.8	32	377.6	14.10	451.20
K-Series Bar Joist-Rod Web: 28K7	11.8	32	377.6	14.10	451.20
	Total Weight		95638.093	Total	122973.92

Total Cost of Framing Steel	1028047.12

Appendix O: Open-Web Bar Joist Steel Framing Costs (Revised Design)

Structural Framing Schedule 2

Family and Type	Length	W (lb/ft)	Weight (lbs)	Cost per foot	Total Cost
W-Wide Flange: W14X22	15.69	22	345.18	$46.00	$721.74
W-Wide Flange: W14X22	15.69	22	345.18	$46.00	$721.74
W-Wide Flange: W14X22	15.48	22	340.56	$46.00	$712.08
W-Wide Flange: W14X22	15.48	22	340.56	$46.00	$712.08
W-Wide Flange: W16X26	21.44	26	557.44	$46.00	$986.24
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	14	26	364	$46.00	$644.00
W-Wide Flange: W16X26	22.01	26	572.26	$46.00	$1,012.46
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W18X35	21.44	35	750.4	$62.00	$1,329.28
W-Wide Flange: W14X22	13	22	286	$46.00	$598.00
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	15.69	40	627.6	$69.50	$1,090.46
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W21X44	21.43	44	942.92	$74.50	$1,596.54
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W24X62	28.91	62	1792.42	$102.00	$2,948.82
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	29.33	62	1818.46	$102.00	$2,991.66
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W21X44	28.94	44	1273.36	$74.50	$2,156.03
W-Wide Flange: W21X44	28.96	44	1274.24	$74.50	$2,157.52
W-Wide Flange: W18X40	18.96	40	758.4	$69.50	$1,317.72
W-Wide Flange: W8X31	17.78	31	551.18	$58.50	$1,040.13
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80

W-Wide Flange: W18X35	33	35	1155	$62.00	$2,046.00
W-Wide Flange: W16X26	19.17	26	498.42	$46.00	$881.82
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W18X40	31	40	1240	$69.50	$2,154.50
W-Wide Flange: W21X44	29.46	44	1296.24	$170.00	$5,008.20
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10
W-Wide Flange: W21X44	32.46	44	1428.24	$170.00	$5,518.20
W-Wide Flange: W18X40	17.78	40	711.2	$62.00	$1,102.36
W-Wide Flange: W18X40	18.96	40	758.4	$62.00	$1,175.52
W-Wide Flange: W18X40	28.96	40	1158.4	$62.00	$1,795.52
W-Wide Flange: W18X40	28.94	40	1157.6	$62.00	$1,794.28
W-Wide Flange: W18X40	32.46	40	1298.4	$62.00	$2,012.52
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66
W-Wide Flange: W18X40	30.93	40	1237.2	$62.00	$1,917.66
W-Wide Flange: W18X40	29.46	40	1178.4	$62.00	$1,826.52
W-Wide Flange: W16X26	17.21	26	447.46	$46.00	$791.66
W-Wide Flange: W16X26	14.64	26	380.64	$46.00	$673.44
W-Wide Flange: W16X26	16.13	26	419.38	$46.00	$741.98
W-Wide Flange: W18X40	28.96	40	1158.4	$62.00	$1,795.52
W-Wide Flange: W16X26	7.78	26	202.28	$46.00	$357.88
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07
W-Wide Flange: W18X40	15.28	40	611.2	$69.50	$1,061.96

W-Wide Flange: W21X50	21.45	50	1072.5	$83.50	$1,791.08
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07
W-Wide Flange: W24X55	28.93	55	1591.15	$90.50	$2,618.17
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W21X50	21.43	50	1071.5	$83.50	$1,789.41
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W24X62	28.91	62	1792.42	$102.00	$2,948.82
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	29.45	62	1825.9	$102.00	$3,003.90
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00

W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00
HSS16X8X5/16	19.09	48.9	933.501	$70.40	$65,718.47
HSS16X8X5/16	30.93	48.9	1512.477	$70.40	$106,478.38
HSS16X8X5/16	29.46	48.9	1440.594	$70.40	$101,417.82
W-Wide Flange: W24X55	31	55	1705	$90.50	$2,805.50
W-Wide Flange: W21X44	29	44	1276	$74.50	$2,160.50
W-Wide Flange: W16X26	7.78	26	202.28	$46.00	$357.88
W-Wide Flange: W24X55	31	55	1705	$90.50	$2,805.50
W-Wide Flange: W24X68	38.83	68	2640.44	$111.00	$4,310.13
W-Wide Flange: W18X35	28.96	35	1013.6	$62.00	$1,795.52
W-Wide Flange: W16X26	16.13	26	419.38	$46.00	$741.98
W-Wide Flange: W16X26	14.64	26	380.64	$46.00	$673.44
W-Wide Flange: W16X26	17.21	26	447.46	$46.00	$791.66
W-Wide Flange: W18X40	29.46	40	1178.4	$69.50	$2,047.47
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64
W-Wide Flange: W18X40	32.46	40	1298.4	$69.50	$2,255.97
W-Wide Flange: W21X44	28.94	44	1273.36	$74.50	$2,156.03
W-Wide Flange: W21X44	28.96	44	1274.24	$74.50	$2,157.52
W-Wide Flange: W16X31	18.96	31	587.76	$54.00	$1,023.84
W-Wide Flange: W16X31	17.78	31	551.18	$54.00	$960.12
W-Wide Flange: W21X55	32.46	55	1785.3	$83.50	$2,710.41
W-Wide Flange: W21X50	30.93	50	1546.5	$83.50	$2,582.66
W-Wide Flange: W21X44	30.93	44	1360.92	$74.50	$2,304.29
W-Wide Flange: W12X19	11.42	19	216.98	$40.50	$462.51
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07
W-Wide Flange: W21X48	28.93	48	1388.64	$83.50	$2,415.66
W-Wide Flange: W14X22	31	22	682	$46.00	$1,426.00
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00
W-Wide Flange: W18X35	30	35	1050	$62.00	$1,860.00
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00
W-Wide Flange: W14X22	32	22	704	$74.50	$2,384.00
W-Wide Flange: W14X22	32	22	704	$74.50	$2,384.00
W-Wide Flange: W14X22	32	22	704	$74.50	$2,384.00

W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08
W-Wide Flange: W16X31	33	31	1023	$54.00	$1,782.00
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00
W-Wide Flange: W21X55	32	55	1760	$102.00	$3,264.00
W-Wide Flange: W21X48	29.45	48	1413.6	$83.50	$2,459.08
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91
W-Wide Flange: W21X48	29	48	1392	$83.50	$2,421.50
W-Wide Flange: W21X48	28.93	48	1388.64	$83.50	$2,415.66
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86
W-Wide Flange: W27X84	28.93	84	2430.12	$134.00	$3,876.62
W-Wide Flange: W24X68	28.91	68	1965.88	$111.00	$3,209.01
W-Wide Flange: W18X40	38.42	40	1536.8	$69.50	$2,670.19
W-Wide Flange: W14X22	8.79	22	193.38	$46.00	$404.34
W-Wide Flange: W14X22	8.79	22	193.38	$46.00	$404.34
W-Wide Flange: W21X44	37.77	44	1661.88	$74.50	$2,813.87
W-Wide Flange: W21X44	30	44	1320	$74.50	$2,235.00
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00
W-Wide Flange: W21X48	30	48	1440	$83.50	$2,505.00
W-Wide Flange: W24X55	30.93	55	1701.15	$102.00	$3,154.86
W-Wide Flange: W24X55	30.93	55	1701.15	$102.00	$3,154.86
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08
W-Wide Flange: W14X22	9.79	22	215.38	$46.00	$450.34
W-Wide Flange: W14X22	21.58	22	474.76	$46.00	$992.68
W-Wide Flange: W14X22	9.25	22	203.5	$46.00	$425.50
W-Wide Flange: W18X40	38.29	40	1531.6	$69.50	$2,661.16
W-Wide Flange: W18X40	38.3	40	1532	$69.50	$2,661.85
W-Wide Flange: W18X40	30	40	1200	$69.50	$2,085.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W12X26	32	26	832	$46.50	$1,488.00

W-Wide Flange: W16X26	32	26	832	$46.50	$1,488.00
W-Wide Flange: W16X26	32	26	832	$46.50	$1,488.00
W-Wide Flange: W12X19	12.6	19	239.4	$40.50	$510.30
W-Wide Flange: W12X19	12.8	19	243.2	$40.50	$518.40
W-Wide Flange: W12X19	14	19	266	$40.50	$567.00
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W8X24	20.03	24	480.72	$48.00	$961.44
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X31	32	31	992	$46.00	$1,472.00
W-Wide Flange: W12X19	26.5	19	503.5	$40.50	$1,073.25
W-Wide Flange: W16X26	15	26	390	$46.00	$690.00
W-Wide Flange: W12X19	11.33	19	215.27	$40.50	$458.87
W-Wide Flange: W14X22	20.67	22	454.74	$46.00	$950.82
W-Wide Flange: W14X22	31.17	22	685.74	$46.00	$1,433.82
W-Wide Flange: W14X22	22.67	22	498.74	$46.00	$1,042.82
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W14X22	13	22	286	$46.00	$598.00
W-Wide Flange: W8X24	20	24	480	$48.00	$960.00
W-Wide Flange: W12X19	22.5	19	427.5	$40.50	$911.25
W-Wide Flange: W8X15	14	15	210	$33.00	$462.00
W-Wide Flange: W8X15	14	15	210	$33.00	$462.00
W-Wide Flange: W8X15	9.15	15	137.25	$33.00	$301.95
W-Wide Flange: W8X15	8.89	15	133.35	$33.00	$293.37
W-Wide Flange: W8X15	8.63	15	129.45	$33.00	$284.79
W-Wide Flange: W8X15	9.42	15	141.3	$33.00	$310.86
W-Wide Flange: W16X26	20	26	520	$46.00	$920.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	20.33	26	528.58	$46.00	$935.18
W-Wide Flange: W16X26	10.17	26	264.42	$46.00	$467.82
W-Wide Flange: W14X22	20.02	22	440.44	$46.00	$920.92
W-Wide Flange: W10X17	9.05	17	153.85	$44.00	$398.20
W-Wide Flange: W10X17	9.26	17	157.42	$44.00	$407.44
W-Wide Flange: W10X17	9.46	17	160.82	$44.00	$416.24
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50

W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50
W-Wide Flange: W8X15	5	15	75	$33.00	$165.00
W-Wide Flange: W8X15	5	15	75	$33.00	$165.00
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W10X17	9.58	17	162.86	$44.00	$421.52
W-Wide Flange: W8X15	2.67	15	40.05	$33.00	$88.11
W-Wide Flange: W12X19	10.21	19	193.99	$40.50	$413.51
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75
W-Wide Flange: W12X19	16.71	19	317.49	$40.50	$676.76
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00
W-Wide Flange: W12X19	9.88	19	187.72	$40.50	$400.14
W-Wide Flange: W8X15	9.88	15	148.2	$33.00	$326.04
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W12X19	9.88	19	187.72	$40.50	$400.14
W-Wide Flange: W12X19	9.88	19	187.72	$40.50	$400.14
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W12X19	9.88	19	187.72	$46.00	$454.48
W-Wide Flange: W12X19	9.88	19	187.72	$46.00	$454.48
W-Wide Flange: W10X17	9.58	17	162.86	$44.00	$421.52
W-Wide Flange: W8X15	2.67	15	40.05	$33.00	$88.11
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W12X19	9.42	19	178.98	$40.50	$381.51
W-Wide Flange: W12X19	9.42	19	178.98	$40.50	$381.51
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00

W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00
W-Wide Flange: W14X22	28.77	22	632.94	$46.00	$1,323.42
W-Wide Flange: W14X22	23.45	22	515.9	$46.00	$1,078.70
W-Wide Flange: W8X15	11.95	15	179.25	$33.00	$394.35
W-Wide Flange: W8X15	6.97	15	104.55	$33.00	$230.01
W-Wide Flange: W12X19	4.57	19	86.83	$40.50	$185.09
W-Wide Flange: W12X19	7.81	19	148.39	$40.50	$316.31
W-Wide Flange: W12X19	9.01	19	171.19	$40.50	$364.91
W-Wide Flange: W14X22	22.85	22	502.7	$46.00	$1,051.10
W-Wide Flange: W12X19	14.48	19	275.12	$40.50	$586.44
W-Wide Flange: W12X19	13.16	19	250.04	$40.50	$532.98
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00
W-Wide Flange: W16X26	13.67	26	355.42	$46.00	$628.82
W-Wide Flange: W14X22	20.67	22	454.74	$46.00	$950.82
W-Wide Flange: W12X19	11.33	19	215.27	$40.50	$458.87
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W10X17	6.83	17	116.11	$44.00	$300.52
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W10X17	8.83	17	150.11	$44.00	$388.52
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00

W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39
W-Wide Flange: W12X19	4.11	19	78.09	$40.50	$166.46
W-Wide Flange: W12X19	10	19	190	$40.50	$405.00
W-Wide Flange: W12X19	10	19	190	$40.50	$405.00
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75
W-Wide Flange: W12X19	7.5	19	142.5	$40.50	$303.75
W-Wide Flange: W12X19	16.71	19	317.49	$40.50	$676.76
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00
W-Wide Flange: W16X26	22	26	572	$46.00	$1,012.00
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00
W-Wide Flange: W14X22	29.71	22	653.62	$46.00	$1,366.66
W-Wide Flange: W14X22	28.3	22	622.6	$46.00	$1,301.80
W-Wide Flange: W12X19	25.49	19	484.31	$40.50	$1,032.35
W-Wide Flange: W12X19	19.36	19	367.84	$40.50	$784.08
W-Wide Flange: W12X14	7.95	14	111.3	$31.00	$246.45
W-Wide Flange: W12X14	4.73	14	66.22	$31.00	$146.63
W-Wide Flange: W12X14	2.35	14	32.9	$31.00	$72.85
W-Wide Flange: W12X14	4.93	14	69.02	$31.00	$152.83
W-Wide Flange: W12X14	3.72	14	52.08	$31.00	$115.32
W-Wide Flange: W12X14	10	14	140	$31.00	$310.00
W-Wide Flange: W12X14	10	14	140	$31.00	$310.00
W-Wide Flange: W12X14	8	14	112	$31.00	$248.00
W-Wide Flange: W10X12	8	12	96	$28.50	$228.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00
W-Wide Flange: W12X14	6.67	14	93.38	$31.00	$206.77
W-Wide Flange: W14X22	23	22	506	$46.00	$1,058.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00

W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
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W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00
W-Wide Flange: W16X26	22.85	26	594.1	$46.00	$1,051.10
W-Wide Flange: W12X14	17.19	14	240.66	$31.00	$532.89
W-Wide Flange: W12X14	18.18	14	254.52	$31.00	$563.58
W-Wide Flange: W12X14	19.17	14	268.38	$31.00	$594.27
W-Wide Flange: W12X14	14.81	14	207.34	$31.00	$459.11
W-Wide Flange: W12X14	13.82	14	193.48	$31.00	$428.42
W-Wide Flange: W12X14	12.83	14	179.62	$31.00	$397.73
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23

W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23
W-Wide Flange: W21X48	32	48	1536	$83.50	$2,672.00
W-Wide Flange: W12X14	10.33	14	144.62	$31.00	$320.23
W-Wide Flange: W12X14	10.33	14	144.62	$31.00	$320.23
W-Wide Flange: W12X14	13.5	14	189	$31.00	$418.50
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00
W-Wide Flange: W6X25	10.33	25	258.25	$41.00	$423.53
W-Wide Flange: W12X14	5.79	14	81.06	$31.00	$179.49
W-Wide Flange: W12X14	5.79	14	81.06	$31.00	$179.49
W-Wide Flange: W12X14	6.92	14	96.88	$31.00	$214.52
W-Wide Flange: W8X10	6.33	10	63.3	$25.50	$161.42
W-Wide Flange: W12X19	9.46	19	179.74	$40.50	$383.13
W-Wide Flange: W12X19	11.96	19	227.24	$40.50	$484.38
W-Wide Flange: W6X25	9.88	25	247	$25.50	$251.94
W-Wide Flange: W12X14	6.08	14	85.12	$31.00	$188.48
W-Wide Flange: W12X14	6.08	14	85.12	$31.00	$188.48
W-Wide Flange: W10X12	5.88	12	70.56	$28.50	$167.58
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00
W-Wide Flange: W18X35	33	35	1155	$62.00	$2,046.00
W-Wide Flange: W18X35	33	35	1155	$62.00	$2,046.00
W-Wide Flange: W18X40	33	40	1320	$69.50	$2,293.50
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01
W-Wide Flange: W8X10	10	10	100	$25.50	$255.00
W-Wide Flange: W8X10	10	10	100	$25.50	$255.00
W-Wide Flange: W8X10	10	10	100	$25.50	$255.00
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69

W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40
W-Wide Flange: W16X31	38.83	31	1203.73	$54.00	$2,096.82
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50
HSS6X6X3/8	16.09	27.4	440.866	$22.10	$9,743.14
HSS6X6X3/8	16.09	27.4	440.866	$22.10	$9,743.14
HSS6X6X3/8	17.15	27.4	469.91	$22.10	$10,385.01
HSS6X6X3/8	17.15	27.4	469.91	$22.10	$10,385.01
HSS5X5X3/8	17.82	22.3	397.386	$14.90	$5,921.05
HSS5X5X3/8	17.82	22.3	397.386	$14.90	$5,921.05
HSS5X5X3/8	16.99	22.3	378.877	$14.90	$5,645.27
HSS5X5X3/8	16.99	22.3	378.877	$14.90	$5,645.27
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00
		Total (lbs)	315216.19	Total Cost	$905,073.20

	W (lb/ft)	Length	Weight	Cost per foot	Total Cost
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92

K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 16K5	7.5	16.67	125.025	$11.65	$194.21
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88

K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50

K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	30.91	370.92	$14.75	$455.92
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 16K5	7.5	20.33	152.475	$11.65	$236.84
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 16K5	7.5	19.99	149.925	$11.65	$232.88
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86

K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80

K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 24K5	9.3	24	223.2	$11.95	$286.80
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	$12.95	$259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	$12.95	$259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	$12.95	$259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	$12.95	$259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	$12.95	$259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	$12.95	$259.00
K-Series Bar Joist-Rod Web: 18K10	11.7	20	234	$12.95	$259.00
K-Series Bar Joist-Rod Web: 24K5	9.3	22.5	209.25	$11.95	$268.88
K-Series Bar Joist-Rod Web: 24K5	9.3	22.5	209.25	$11.95	$268.88
K-Series Bar Joist-Rod Web: 24K5	9.3	22.5	209.25	$11.95	$268.88
K-Series Bar Joist-Rod Web: 24K5	9.3	22.5	209.25	$11.95	$268.88
K-Series Bar Joist-Rod Web: 24K5	9.3	22.5	209.25	$11.95	$268.88
K-Series Bar Joist-Rod Web: 24K5	9.3	22.5	209.25	$11.95	$268.88
K-Series Bar Joist-Rod Web: 24K5	9.3	22.5	209.25	$11.95	$268.88
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	30	369	$14.50	$435.00
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86
K-Series Bar Joist-Rod Web: 30K7	12.3	29.99	368.877	$14.50	$434.86

K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00

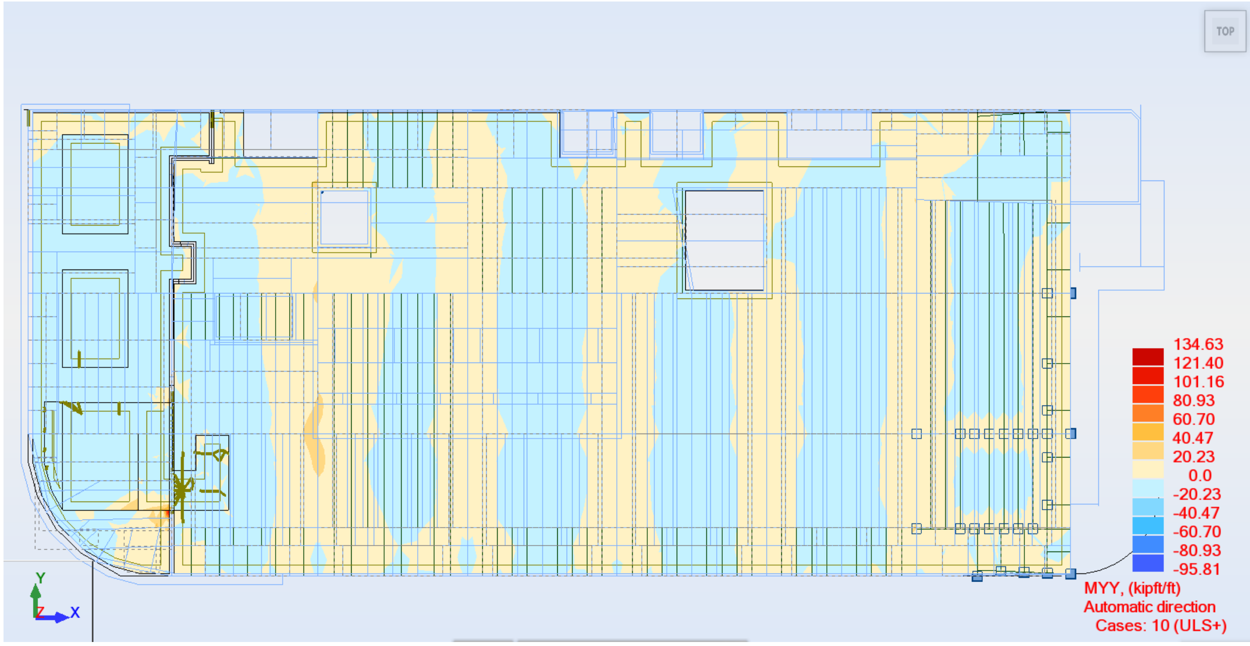
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	$10.85	$216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	$10.85	$216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	$10.85	$216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	$10.85	$216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	19.99	143.928	$10.85	$216.89
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 18K4	7.2	20	144	$10.85	$217.00
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35

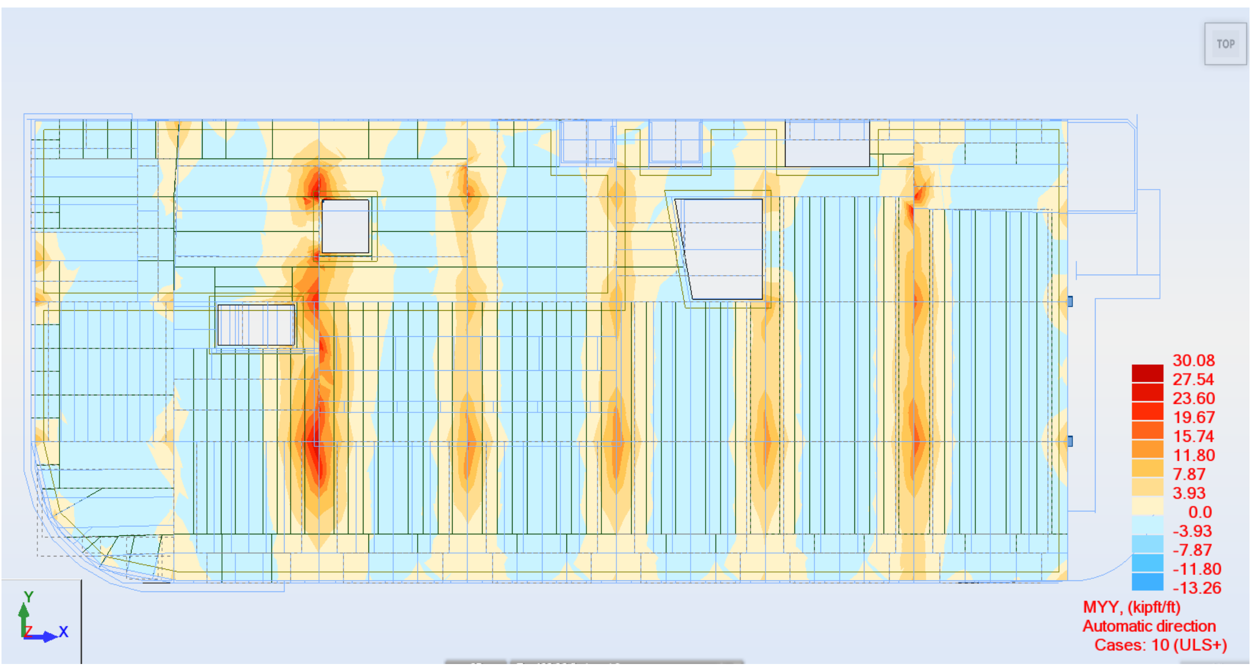
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	29.99	359.88	$14.75	$442.35
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	30	360	$14.75	$442.50
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 24K9	12	22.5	270	$14.75	$331.88
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 26K9	12.2	29.99	365.878	$15.35	$460.35
K-Series Bar Joist-Rod Web: 28K7	11.8	29.99	353.882	$14.10	$422.86
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	$14.10	$423.00
K-Series Bar Joist-Rod Web: 28K7	11.8	30	354	$14.10	$423.00

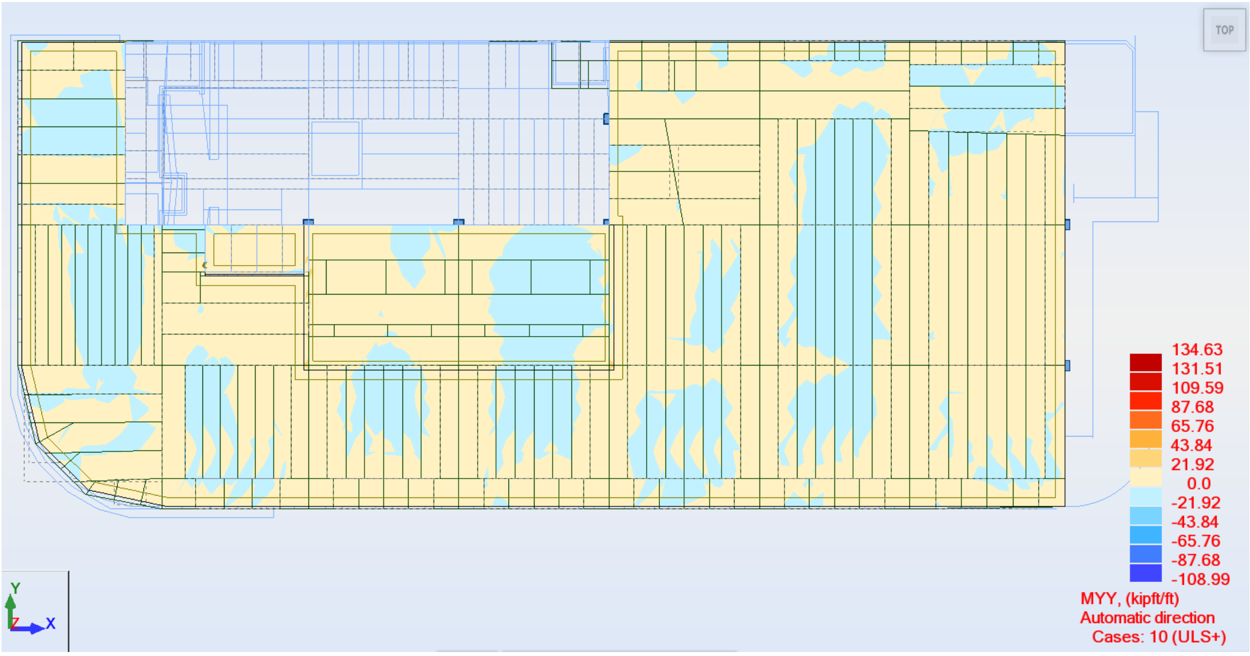
K-Series Bar Joist-Rod Web: 28K7	11.8	32	377.6	$14.10	$451.20
K-Series Bar Joist-Rod Web: 28K7	11.8	32	377.6	$14.10	$451.20
K-Series Bar Joist-Rod Web: 28K7	11.8	32	377.6	$14.10	$451.20
	Total Weight		98450.475	Total	$124,793.30

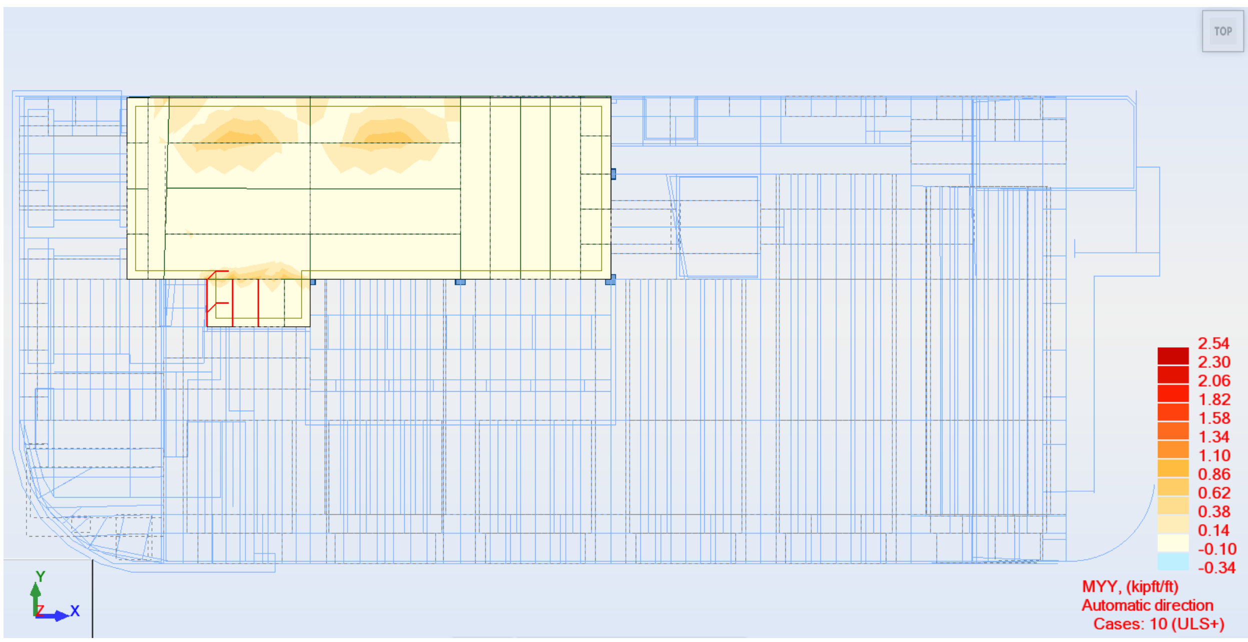
Total Cost of Framing Steel	(web joists similarized for constructability)	$1,029,866.49
Total Weight of structural Steel(lbs)	(web joists similarized for constructability)	413666.665
Total Cost of Framing Steel	(first web joist design)	$1,028,047.12
Total Weight of structural Steel (lbs)	(first web joist design)	410854.283

Appendix P: Original Open-Web Bar Joist MYY Robot Maps






TOP
134.63
131.51
109.59
87.68
65.76
43.84
21.92
0.0
-21.92
-43.84
-65.76
-87.68
-108.99
MYY, (kipft/ft)
Automatic direction
Cases: 10 (ULS+)
Y
Z
X


TOP
2.54
2.30
2.06
1.82
1.58
1.34
1.10
0.86
0.62
0.38
0.14
-0.10
-0.34
MYY, (kipft/ft)
Automatic direction
Cases: 10 (ULS+)
Y
Z
X

Appendix Q: Precast Concrete Hand Calculations

PRECAST CONCRETE

Hollow-Core Selection: (PCI.ORG, 3.6 Hollow-Core Load Tables)

All slabs to have 2" Normal Weight Topping

Floor 2:

Spans = 30', 32', 33', 14' (Cantilevered: 14')

Loads: Topped members have a tolerance of 15 lb/ft^2 dead load (MEP)

Office Area Live Load = 100 psf

For all spans;

4'-0" x 8" Normal Weight Concrete

78-S provides safe superimposed load of 119 lb/ft^2 for 32'

" " " " 106 lb/ft^2 for 33'

" " " " 472 lb/ft^2 for 14'

$\boxed{4HC8+2}$

Floor 3:

Spans = 33', 32', 31', Rounded edge,

Loads = Same as floor 2:

Precast selection: 4'-0 x 8" 78-S $\boxed{4HC8+2}$

Roof:

Spans = 33', 32', 31', 30'

Live load = 127.75 psf

Precast Selection: 4'-10" 68-S $\boxed{4HC10+2}$

Mech Roof:

Spans = 32', 30'

Live Load = 38.5 psf

Precast selection: 4'-8" 76-S $\boxed{4HC8+2}$

Dead Loads:

4HC8+2 DL = 81 lb/ft^2

4HC10+2 DL = 93 lb/ft^2

*Note: The slabs are designed to support 15 lb/ft^2 additionally.

Appendix R: Precast Planks Steel and Concrete Costs

Structural Framing Schedule

Family and Type	Length	W (lb/ft)	Weight (lb)	Cost per unit	Total Cost	Cost per Pound
W-Wide Flange: W14X22	15.69	22	345.18	$46.00	$721.74	$2.09
W-Wide Flange: W14X22	15.69	22	345.18	$46.00	$721.74	$2.09
W-Wide Flange: W14X22	15.48	22	340.56	$46.00	$712.08	$2.09
W-Wide Flange: W14X22	15.48	22	340.56	$46.00	$712.08	$2.09
W-Wide Flange: W16X26	21.44	26	557.44	$46.00	$986.24	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	14	26	364	$46.00	$644.00	$1.77
W-Wide Flange: W16X26	22.01	26	572.26	$46.00	$1,012.46	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W18X35	21.44	35	750.4	$62.00	$1,329.28	$1.77
W-Wide Flange: W14X22	13	22	286	$46.00	$598.00	$2.09
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	15.69	40	627.6	$69.50	$1,090.46	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W21X44	21.43	44	942.92	$74.50	$1,596.54	$1.69
W-Wide Flange:	21.44	44	943.36	$74.50	$1,597.28	$1.69

W21X44						
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W24X62	28.91	62	1792.42	$102.00	$2,948.82	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	29.33	62	1818.46	$102.00	$2,991.66	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W21X44	28.94	44	1273.36	$74.50	$2,156.03	$1.69
W-Wide Flange: W21X44	28.96	44	1274.24	$74.50	$2,157.52	$1.69
W-Wide Flange: W18X40	18.96	40	758.4	$69.50	$1,317.72	$1.74
W-Wide Flange: W8X31	17.78	31	551.18	$58.50	$1,040.13	$1.89
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X35	33	35	1155	$62.00	$2,046.00	$1.77
W-Wide Flange: W16X26	19.17	26	498.42	$46.00	$881.82	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange:	32	31	992	$54.00	$1,728.00	$1.74

W16X31						
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W18X40	31	40	1240	$69.50	$2,154.50	$1.74
W-Wide Flange: W21X44	29.46	44	1296.24	$170.00	$5,008.20	$3.86
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$3.86
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$3.86
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$3.86
W-Wide Flange: W21X44	30.93	44	1360.92	$170.00	$5,258.10	$3.86
W-Wide Flange:	32.46	44	1428.24	$170.00	$5,518.20	$3.86

W21X44						
W-Wide Flange: W18X40	17.78	40	711.2	$69.50	$1,235.71	$1.74
W-Wide Flange: W18X40	18.96	40	758.4	$69.50	$1,317.72	$1.74
W-Wide Flange: W18X40	28.96	40	1158.4	$69.50	$2,012.72	$1.74
W-Wide Flange: W18X40	28.94	40	1157.6	$69.50	$2,011.33	$1.74
W-Wide Flange: W18X40	32.46	40	1298.4	$69.50	$2,255.97	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	29.46	40	1178.4	$69.50	$2,047.47	$1.74
W-Wide Flange: W18X40	28.96	40	1158.4	$69.50	$2,012.72	$1.74
W-Wide Flange: W16X26	7.78	26	202.28	$46.00	$357.88	$1.77
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07	$1.65
W-Wide Flange: W18X40	15.28	40	611.2	$69.50	$1,061.96	$1.74
W-Wide Flange: W21X50	21.45	50	1072.5	$83.50	$1,791.08	$1.67
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07	$1.65
W-Wide Flange: W24X55	28.93	55	1591.15	$90.50	$2,618.17	$1.65
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange:	15.81	40	632.4	$69.50	$1,098.80	$1.74

W18X40						
W-Wide Flange: W21X50	21.43	50	1071.5	$83.50	$1,789.41	$1.67
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W24X62	28.91	62	1792.42	$102.00	$2,948.82	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	29.45	62	1825.9	$102.00	$3,003.90	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W24X62	29.46	62	1826.52	$102.00	$3,004.92	$1.65
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange:	32	26	832	$46.00	$1,472.00	$1.77

W16X26						
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$1.74
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$1.74
HSS16X8X5/16	19.09	48.9	933.501	$70.40	$65,718.47	$70.40
HSS16X8X5/16	30.93	48.9	1512.477	$70.40	$106,478.38	$70.40
HSS16X8X5/16	29.46	48.9	1440.594	$70.40	$101,417.82	$70.40
W-Wide Flange: W24X55	31	55	1705	$90.50	$2,805.50	$1.65
W-Wide Flange: W21X44	29	44	1276	$74.50	$2,160.50	$1.69
W-Wide Flange: W16X26	7.78	26	202.28	$46.00	$357.88	$1.77
W-Wide Flange: W24X55	31	55	1705	$90.50	$2,805.50	$1.65

W-Wide Flange: W24X68	38.83	68	2640.44	$111.00	$4,310.13	$1.63
W-Wide Flange: W18X35	28.96	35	1013.6	$62.00	$1,795.52	$1.77
W-Wide Flange: W18X40	29.46	40	1178.4	$69.50	$2,047.47	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	30.93	40	1237.2	$69.50	$2,149.64	$1.74
W-Wide Flange: W18X40	32.46	40	1298.4	$69.50	$2,255.97	$1.74
W-Wide Flange: W21X44	28.94	44	1273.36	$74.50	$2,156.03	$1.69
W-Wide Flange: W21X44	28.96	44	1274.24	$74.50	$2,157.52	$1.69
W-Wide Flange: W16X31	18.96	31	587.76	$54.00	$1,023.84	$1.74
W-Wide Flange: W16X31	17.78	31	551.18	$54.00	$960.12	$1.74
W-Wide Flange: W21X55	32.46	55	1785.3	$83.50	$2,710.41	$1.52
W-Wide Flange: W21X50	30.93	50	1546.5	$83.50	$2,582.66	$1.67
W-Wide Flange: W21X44	30.93	44	1360.92	$74.50	$2,304.29	$1.69
W-Wide Flange: W12X19	11.42	19	216.98	$40.50	$462.51	$2.13
W-Wide Flange: W24X55	28.94	55	1591.7	$90.50	$2,619.07	$1.65
W-Wide Flange: W21X48	28.93	48	1388.64	$83.50	$2,415.66	$1.74
W-Wide Flange: W14X22	31	22	682	$46.00	$1,426.00	$2.09
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$2.09
W-Wide Flange: W18X35	30	35	1050	$62.00	$1,860.00	$1.77
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$1.77

W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$1.77
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$1.74
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W21X44	21.44	44	943.36	$74.50	$1,597.28	$1.69
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00	$1.69
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$2.09
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$2.09
W-Wide Flange: W14X22	32	22	704	$46.00	$1,472.00	$2.09
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08	$1.74
W-Wide Flange: W16X31	33	31	1023	$54.00	$1,782.00	$1.74
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$1.77
W-Wide Flange: W21X55	32	55	1760	$83.50	$2,672.00	$1.52
W-Wide Flange: W21X48	29.45	48	1413.6	$83.50	$2,459.08	$1.74
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$1.74
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$1.74
W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$1.74

W-Wide Flange: W21X48	29.46	48	1414.08	$83.50	$2,459.91	$1.74
W-Wide Flange: W21X48	29	48	1392	$83.50	$2,421.50	$1.74
W-Wide Flange: W21X48	28.93	48	1388.64	$83.50	$2,415.66	$1.74
W-Wide Flange: W24X62	28.93	62	1793.66	$102.00	$2,950.86	$1.65
W-Wide Flange: W27X84	28.93	84	2430.12	$134.00	$3,876.62	$1.60
W-Wide Flange: W24X68	28.91	68	1965.88	$111.00	$3,209.01	$1.63
W-Wide Flange: W18X40	38.42	40	1536.8	$69.50	$2,670.19	$1.74
W-Wide Flange: W14X22	8.79	22	193.38	$46.00	$404.34	$2.09
W-Wide Flange: W14X22	8.79	22	193.38	$46.00	$404.34	$2.09
W-Wide Flange: W21X44	37.77	44	1661.88	$74.50	$2,813.87	$1.69
W-Wide Flange: W21X44	30	44	1320	$74.50	$2,235.00	$1.69
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00	$1.69
W-Wide Flange: W21X44	32	44	1408	$74.50	$2,384.00	$1.69
W-Wide Flange: W21X48	30	48	1440	$83.50	$2,505.00	$1.74
W-Wide Flange: W24X55	30.93	55	1701.15	$90.50	$2,799.17	$1.65
W-Wide Flange: W24X55	30.93	55	1701.15	$90.50	$2,799.17	$1.65
W-Wide Flange: W18X40	15.81	40	632.4	$69.50	$1,098.80	$1.74
W-Wide Flange: W18X40	21.44	40	857.6	$69.50	$1,490.08	$1.74
W-Wide Flange: W14X22	12.08	22	265.76	$46.00	$555.68	$2.09
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00	$2.09
W-Wide Flange: W14X22	11.54	22	253.88	$46.00	$530.84	$2.09
W-Wide Flange: W18X40	38.29	40	1531.6	$69.50	$2,661.16	$1.74

W-Wide Flange: W18X40	38.3	40	1532	$69.50	$2,661.85	$1.74
W-Wide Flange: W18X40	30	40	1200	$69.50	$2,085.00	$1.74
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W12X19	13.17	19	250.23	$40.50	$533.39	$2.13
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W12X19	13.17	19	250.23	$40.50	$533.39	$2.13
W-Wide Flange: W12X19	13.17	19	250.23	$40.50	$533.39	$2.13
W-Wide Flange: W12X26	32	26	832	$46.50	$1,488.00	$1.79
W-Wide Flange: W8X24	20.03	24	480.72	$48.00	$961.44	$2.00
W-Wide Flange: W12X19	13.17	19	250.23	$40.50	$533.39	$2.13
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$1.74
W-Wide Flange: W16X26	15	26	390	$46.00	$690.00	$1.77
W-Wide Flange: W12X19	11.33	19	215.27	$40.50	$458.87	$2.13
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W14X22	13	22	286	$46.00	$598.00	$2.09
W-Wide Flange: W8X24	20	24	480	$48.00	$960.00	$2.00

W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W12X19	22.5	19	427.5	$40.50	$911.25	$2.13
W-Wide Flange: W8X15	14	15	210	$33.00	$462.00	$2.20
W-Wide Flange: W8X15	14	15	210	$33.00	$462.00	$2.20
W-Wide Flange: W8X15	9.15	15	137.25	$33.00	$301.95	$2.20
W-Wide Flange: W8X15	8.89	15	133.35	$33.00	$293.37	$2.20
W-Wide Flange: W8X15	8.63	15	129.45	$33.00	$284.79	$2.20
W-Wide Flange: W8X15	9.42	15	141.3	$33.00	$310.86	$2.20
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10.17	17	172.89	$44.00	$447.48	$2.59
W-Wide Flange: W10X17	10.17	17	172.89	$44.00	$447.48	$2.59
W-Wide Flange: W16X26	10.17	26	264.42	$46.00	$467.82	$1.77
W-Wide Flange: W14X22	20.02	22	440.44	$46.00	$920.92	$2.09
W-Wide Flange: W10X17	9.05	17	153.85	$44.00	$398.20	$2.59
W-Wide Flange: W10X17	9.26	17	157.42	$44.00	$407.44	$2.59
W-Wide Flange: W10X17	9.46	17	160.82	$44.00	$416.24	$2.59
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13

W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13
W-Wide Flange: W12X19	5	19	95	$40.50	$202.50	$2.13
W-Wide Flange: W8X15	5	15	75	$33.00	$165.00	$2.20
W-Wide Flange: W8X15	5	15	75	$33.00	$165.00	$2.20
W-Wide Flange: W12X19	11.77	19	223.63	$40.50	$476.69	$2.13
W-Wide Flange: W12X19	11.77	19	223.63	$40.50	$476.69	$2.13
W-Wide Flange: W12X19	11.77	19	223.63	$40.50	$476.69	$2.13
W-Wide Flange: W12X19	11.77	19	223.63	$40.50	$476.69	$2.13
W-Wide Flange: W12X19	11.77	19	223.63	$40.50	$476.69	$2.13
W-Wide Flange: W10X17	9.58	17	162.86	$44.00	$421.52	$2.59
W-Wide Flange: W8X15	4.23	15	63.45	$33.00	$139.59	$2.20
W-Wide Flange: W12X19	11.38	19	216.22	$40.50	$460.89	$2.13
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$1.74
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$1.74
W-Wide Flange: W12X19	11.13	19	211.47	$40.50	$450.77	$2.13
W-Wide Flange: W8X15	11.13	15	166.95	$33.00	$367.29	$2.20

W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W12X19	11.21	19	212.99	$40.50	$454.01	$2.13
W-Wide Flange: W12X19	11.21	19	212.99	$40.50	$454.01	$2.13
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W12X19	11.21	19	212.99	$40.50	$454.01	$2.13
W-Wide Flange: W12X19	11.21	19	212.99	$40.50	$454.01	$2.13
W-Wide Flange: W10X17	9.58	17	162.86	$44.00	$421.52	$2.59
W-Wide Flange: W8X15	4	15	60	$33.00	$132.00	$2.20
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W12X19	9.42	19	178.98	$40.50	$381.51	$2.13
W-Wide Flange: W12X19	9.42	19	178.98	$40.50	$381.51	$2.13
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20

W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W14X22	22.85	22	502.7	$46.00	$1,051.10	$2.09
W-Wide Flange: W12X19	14.48	19	275.12	$40.50	$586.44	$2.13
W-Wide Flange: W12X19	13.16	19	250.04	$40.50	$532.98	$2.13
W-Wide Flange: W16X31	32	31	992	$54.00	$1,728.00	$1.74
W-Wide Flange: W16X26	14.5	26	377	$46.00	$667.00	$1.77
W-Wide Flange: W14X22	20.67	22	454.74	$46.00	$950.82	$2.09
W-Wide Flange: W12X19	11.33	19	215.27	$40.50	$458.87	$2.13
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61	$2.20
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61	$2.20
W-Wide Flange: W8X15	8.17	15	122.55	$33.00	$269.61	$2.20
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$2.13
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$2.13
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$2.13
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$2.13
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$2.13

W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$2.13
W-Wide Flange: W12X19	8.17	19	155.23	$40.50	$330.89	$2.13
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$2.13
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W10X17	6.83	17	116.11	$44.00	$300.52	$2.59
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	30	26	780	$46.00	$1,380.00	$1.77
W-Wide Flange: W10X17	8.83	17	150.11	$44.00	$388.52	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$2.13
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$2.13
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$2.13
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$2.13
W-Wide Flange: W12X19	10	19	190	$40.50	$405.00	$2.13
W-Wide Flange: W12X19	10	19	190	$40.50	$405.00	$2.13
W-Wide Flange: W12X19	5.17	19	98.23	$40.50	$209.39	$2.13
W-Wide Flange: W14X22	22	22	484	$46.00	$1,012.00	$2.09
W-Wide Flange: W12X14	12.08	14	169.12	$31.00	$374.48	$2.21

W-Wide Flange: W12X14	12.08	14	169.12	$31.00	$374.48	$2.21
W-Wide Flange: W12X14	8	14	112	$31.00	$248.00	$2.21
W-Wide Flange: W10X12	8	12	96	$28.50	$228.00	$2.38
W-Wide Flange: W14X22	30	22	660	$28.50	$855.00	$1.30
W-Wide Flange: W14X22	32	22	704	$28.50	$912.00	$1.30
W-Wide Flange: W14X22	32	22	704	$28.50	$912.00	$1.30
W-Wide Flange: W14X22	32	22	704	$28.50	$912.00	$1.30
W-Wide Flange: W14X22	32	22	704	$28.50	$912.00	$1.30
W-Wide Flange: W16X26	33	26	858	$46.00	$1,518.00	$1.77
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21

W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W16X26	22.85	26	594.1	$46.00	$1,051.10	$1.77
W-Wide Flange: W12X14	17.19	14	240.66	$31.00	$532.89	$2.21
W-Wide Flange: W12X14	18.18	14	254.52	$31.00	$563.58	$2.21
W-Wide Flange: W12X14	19.17	14	268.38	$31.00	$594.27	$2.21
W-Wide Flange: W12X14	14.81	14	207.34	$31.00	$459.11	$2.21
W-Wide Flange: W12X14	13.82	14	193.48	$31.00	$428.42	$2.21

W-Wide Flange: W12X14	12.83	14	179.62	$31.00	$397.73	$2.21
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$1.74
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$1.74
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$1.74
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$1.74
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W16X26	32	26	832	$46.00	$1,472.00	$1.77
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$2.21
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$2.21
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$2.21
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$2.21
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$2.21
W-Wide Flange: W12X14	2.42	14	33.88	$31.00	$75.02	$2.21
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$2.21
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$2.21
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$2.21
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$2.21
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$2.21
W-Wide Flange: W12X14	7.33	14	102.62	$31.00	$227.23	$2.21
W-Wide Flange: W21X48	32	48	1536	$83.50	$2,672.00	$1.74

W-Wide Flange: W12X14	10.33	14	144.62	$31.00	$320.23	$2.21
W-Wide Flange: W12X14	10.33	14	144.62	$31.00	$320.23	$2.21
W-Wide Flange: W12X14	13.5	14	189	$31.00	$418.50	$2.21
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$2.21
W-Wide Flange: W6X25	10.33	25	258.25	$41.00	$423.53	$1.64
W-Wide Flange: W12X14	5.79	14	81.06	$31.00	$179.49	$2.21
W-Wide Flange: W12X14	5.79	14	81.06	$31.00	$179.49	$2.21
W-Wide Flange: W12X14	6.92	14	96.88	$31.00	$214.52	$2.21
W-Wide Flange: W8X10	6.33	10	63.3	$25.50	$161.42	$2.55
W-Wide Flange: W12X19	9.46	19	179.74	$40.50	$383.13	$2.13
W-Wide Flange: W12X19	11.96	19	227.24	$40.50	$484.38	$2.13
W-Wide Flange: W6X25	9.88	25	247	$41.00	$405.08	$1.64
W-Wide Flange: W12X14	6.08	14	85.12	$31.00	$188.48	$2.21
W-Wide Flange: W12X14	6.08	14	85.12	$31.00	$188.48	$2.21
W-Wide Flange: W10X12	5.88	12	70.56	$28.50	$167.58	$2.38
W-Wide Flange: W18X40	32	40	1280	$69.50	$2,224.00	$1.74
W-Wide Flange: W18X35	32	35	1120	$62.00	$1,984.00	$1.77
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$2.21
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$2.21
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$2.21
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$2.21
W-Wide Flange: W12X14	4	14	56	$31.00	$124.00	$2.21

W-Wide Flange: W18X40	33	40	1320	$69.50	$2,293.50	$1.74
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$2.21
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$2.21
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$2.21
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$2.21
W-Wide Flange: W12X14	4.71	14	65.94	$31.00	$146.01	$2.21
W-Wide Flange: W8X10	12.08	10	120.8	$25.50	$308.04	$2.55
W-Wide Flange: W8X10	12.08	10	120.8	$25.50	$308.04	$2.55
W-Wide Flange: W8X10	12.08	10	120.8	$25.50	$308.04	$2.55
W-Wide Flange: W18X40	38.83	40	1553.2	$69.50	$2,698.69	$1.74
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$2.21
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$2.21
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$2.21
W-Wide Flange: W12X14	6.4	14	89.6	$31.00	$198.40	$2.21
W-Wide Flange: W16X31	38.83	31	1203.73	$54.00	$2,096.82	$1.74
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50	$2.21
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50	$2.21
W-Wide Flange: W12X14	4.5	14	63	$31.00	$139.50	$2.21
HSS6X6X3/8	16.2	27.4	443.88	$22.10	$9,809.75	$22.10
HSS6X6X3/8	16.2	27.4	443.88	$22.10	$9,809.75	$22.10
HSS6X6X3/8	17.04	27.4	466.896	$22.10	$10,318.40	$22.10
HSS6X6X3/8	17.04	27.4	466.896	$22.10	$10,318.40	$22.10
HSS5X5X3/8	17.82	22.3	397.386	$14.90	$5,921.05	$14.90
HSS5X5X3/8	17.82	22.3	397.386	$14.90	$5,921.05	$14.90
HSS5X5X3/8	16.99	22.3	378.877	$14.90	$5,645.27	$14.90
HSS5X5X3/8	16.99	22.3	378.877	$14.90	$5,645.27	$14.90

W-Wide Flange: W18X40	28.97	40	1158.8	$69.50	$2,013.42	$1.74
W-Wide Flange: W18X40	31	40	1240	$69.50	$2,154.50	$1.74
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W16X26	31	26	806	$46.00	$1,426.00	$1.77
W-Wide Flange: W10X17	10	17	170	$44.00	$440.00	$2.59
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W8X15	10	15	150	$33.00	$330.00	$2.20
W-Wide Flange: W18X40	31	40	1240	$69.50	$2,154.50	$1.74
W-Wide Flange: W18X40	30	40	1200	$69.50	$2,085.00	$1.74
W-Wide Flange: W14X22	31	22	682	$46.00	$1,426.00	$2.09
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W12X14	6	14	84	$31.00	$186.00	$2.21
W-Wide Flange: W16X26	28.93	26	752.18	$46.00	$1,330.78	$1.77
W-Wide Flange: W16X26	28.94	26	752.44	$46.00	$1,331.24	$1.77
W-Wide Flange: W16X26	21.45	26	557.7	$46.00	$986.70	$1.77
W-Wide Flange: W16X26	15.28	26	397.28	$46.00	$702.88	$1.77
W-Wide Flange: W14X22	30	22	660	$46.00	$1,380.00	$2.09
Total			302213.56	(lb)	$875,880.78	

Holloow Core Planks

Family and Type	Length	Width	Sq. Ft.	Cost per Sq. Ft.	Cost
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab:	14.17	4	56.68	$10.35	$586.64

4HC8					
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	14.17	4	56.68	$10.35	$586.64
Hollow Core Slab: 4HC8	14.17	2.5	35.425	$10.35	$366.65
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	2.5	80	$10.35	$828.00
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	19.79	4	79.16	$10.35	$819.31
Hollow Core Slab: 4HC8	19.79	4	79.16	$10.35	$819.31
Hollow Core Slab: 4HC8	19.79	2.5	49.475	$10.35	$512.07
Hollow Core Slab: 4HC8	20.67	4	82.68	$10.35	$855.74
Hollow Core Slab: 4HC8	20.67	4	82.68	$10.35	$855.74
Hollow Core Slab: 4HC8	20.67	4	82.68	$10.35	$855.74
Hollow Core Slab: 4HC8	20.67	4	82.68	$10.35	$855.74
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	6.92	4	27.68	$10.35	$286.49
Hollow Core Slab: 4HC8	6.92	4	27.68	$10.35	$286.49
Hollow Core Slab: 4HC8	6.92	2.5	17.3	$10.35	$179.06
Hollow Core Slab: 4HC8	13.5	4	54	$10.35	$558.90
Hollow Core Slab: 4HC8	13.5	4	54	$10.35	$558.90
Hollow Core Slab: 4HC8	13.5	2.5	33.75	$10.35	$349.31
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	4.33	4	17.32	$10.35	$179.26
Hollow Core Slab: 4HC8	4.33	4	17.32	$10.35	$179.26
Hollow Core Slab: 4HC8	9.58	4	38.32	$10.35	$396.61
Hollow Core Slab: 4HC8	9.58	4	38.32	$10.35	$396.61
Hollow Core Slab: 4HC8	4.33	2.5	10.825	$10.35	$112.04
Hollow Core Slab:	9.58	2.5	23.95	$10.35	$247.88

4HC8					
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab:	33	4	132	$10.35	$1,366.20

4HC8					
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	2.5	82.5	$10.35	$853.88
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	19.79	4	79.16	$10.35	$819.31
Hollow Core Slab: 4HC8	19.79	4	79.16	$10.35	$819.31
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	19.79	4	79.16	$10.35	$819.31
Hollow Core Slab: 4HC8	6.92	4	27.68	$10.35	$286.49
Hollow Core Slab: 4HC8	13.5	4	54	$10.35	$558.90
Hollow Core Slab: 4HC8	6.92	4	27.68	$10.35	$286.49
Hollow Core Slab: 4HC8	6.92	4	27.68	$10.35	$286.49
Hollow Core Slab: 4HC8	13.5	4	54	$10.35	$558.90
Hollow Core Slab: 4HC8	13.5	4	54	$10.35	$558.90
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	7.83	4	31.32	$10.35	$324.16
Hollow Core Slab: 4HC8	7.83	4	31.32	$10.35	$324.16
Hollow Core Slab: 4HC8	7.83	4	31.32	$10.35	$324.16
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	2.5	80	$10.35	$828.00
Hollow Core Slab: 4HC8	13	2.5	32.5	$10.35	$336.38
Hollow Core Slab: 4HC8	12.94	4	51.76	$10.35	$535.72
Hollow Core Slab: 4HC8	12.83	4	51.32	$10.35	$531.16
Hollow Core Slab: 4HC8	12.72	4	50.88	$10.35	$526.61
Hollow Core Slab: 4HC8	12.61	4	50.44	$10.35	$522.05
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	14	4	56	$10.35	$579.60
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab:	31	4	124	$10.35	$1,283.40

4HC8					
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	4	124	$10.35	$1,283.40
Hollow Core Slab: 4HC8	31	2.5	77.5	$10.35	$802.13
Hollow Core Slab: 4HC8	30	2.5	75	$10.35	$776.25
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab:	30	4	120	$10.35	$1,242.00

4HC8					
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	7.58	4	30.32	$10.35	$313.81
Hollow Core Slab: 4HC8	7.58	4	30.32	$10.35	$313.81
Hollow Core Slab: 4HC8	4.63	4	18.52	$10.35	$191.68
Hollow Core Slab: 4HC8	4.63	4	18.52	$10.35	$191.68
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	20.5	4	82	$10.35	$848.70
Hollow Core Slab: 4HC8	20.67	4	82.68	$10.35	$855.74
Hollow Core Slab: 4HC8	20.67	4	82.68	$10.35	$855.74
Hollow Core Slab: 4HC8	20.67	4	82.68	$10.35	$855.74
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	2.5	80	$10.35	$828.00
Hollow Core Slab: 4HC8	19.83	2.5	49.575	$10.35	$513.10
Hollow Core Slab: 4HC8	19.83	4	79.32	$10.35	$820.96
Hollow Core Slab: 4HC8	19.83	4	79.32	$10.35	$820.96
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	15.8	4	63.2	$10.35	$654.12
Hollow Core Slab: 4HC8	15.1	4	60.4	$10.35	$625.14
Hollow Core Slab:	14.39	4	57.56	$10.35	$595.75

4HC8					
Hollow Core Slab: 4HC8	13.68	4	54.72	$10.35	$566.35
Hollow Core Slab: 4HC8	12.98	4	51.92	$10.35	$537.37
Hollow Core Slab: 4HC8	12.27	4	49.08	$10.35	$507.98
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	6.92	4	27.68	$10.35	$286.49
Hollow Core Slab: 4HC8	6.92	4	27.68	$10.35	$286.49
Hollow Core Slab: 4HC8	13.5	4	54	$10.35	$558.90
Hollow Core Slab: 4HC8	13.5	4	54	$10.35	$558.90
Hollow Core Slab: 4HC8	4.33	4	17.32	$10.35	$179.26
Hollow Core Slab: 4HC8	4.33	4	17.32	$10.35	$179.26
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	9.58	4	38.32	$10.35	$396.61
Hollow Core Slab: 4HC8	9.58	4	38.32	$10.35	$396.61
Hollow Core Slab: 4HC8	6.92	2.5	17.3	$10.35	$179.06
Hollow Core Slab: 4HC8	13.5	2.5	33.75	$10.35	$349.31
Hollow Core Slab: 4HC8	4.33	2.5	10.825	$10.35	$112.04
Hollow Core Slab: 4HC8	9.58	2.5	23.95	$10.35	$247.88
Hollow Core Slab: 4HC8	33	2.5	82.5	$10.35	$853.88
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab:	33	4	132	$10.35	$1,366.20

4HC8					
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC8	33	4	132	$10.35	$1,366.20
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab:	31	4	124	$10.40	$1,289.60

4HC10					
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	31	4	124	$10.40	$1,289.60
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab: 4HC10	22	4	88	$10.40	$915.20
Hollow Core Slab:	22	2.5	55	$10.40	$572.00

4HC10					
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	30	4	120	$10.40	$1,248.00
Hollow Core Slab: 4HC10	8	4	32	$10.40	$332.80
Hollow Core Slab: 4HC10	8	4	32	$10.40	$332.80
Hollow Core Slab: 4HC10	8	4	32	$10.40	$332.80
Hollow Core Slab: 4HC10	5.5	4	22	$10.40	$228.80
Hollow Core Slab: 4HC10	5.5	4	22	$10.40	$228.80
Hollow Core Slab: 4HC10	5.5	4	22	$10.40	$228.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab:	32	4	128	$10.40	$1,331.20

4HC10					
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab:	32	4	128	$10.40	$1,331.20

4HC10					
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab:	32	4	128	$10.40	$1,331.20

4HC10					
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab:	32	4	128	$10.40	$1,331.20

4HC10					
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab:	32	4	128	$10.40	$1,331.20

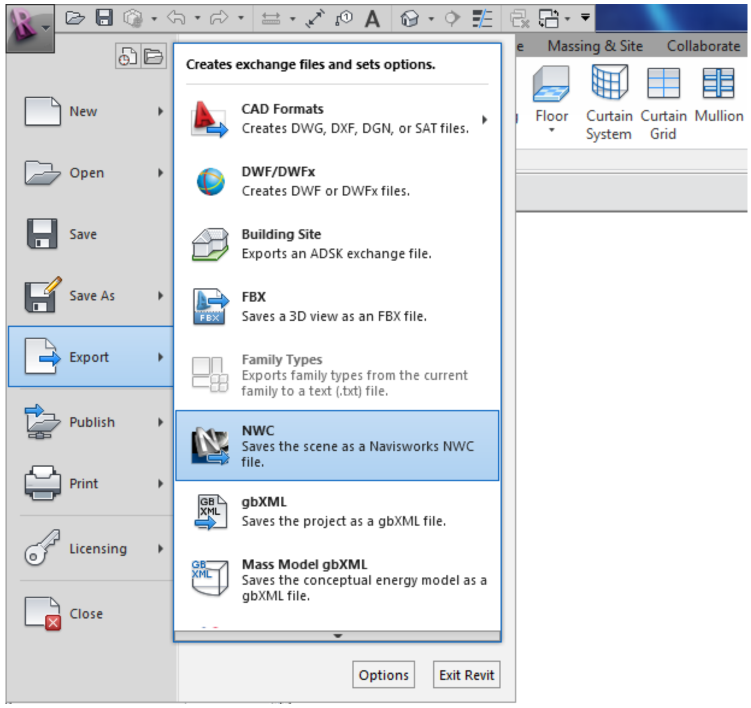
4HC10					
Hollow Core Slab: 4HC10	33	4	132	$10.40	$1,372.80
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	4	128	$10.40	$1,331.20
Hollow Core Slab: 4HC10	32	2.5	80	$10.40	$832.00
Hollow Core Slab: 4HC10	32	2.5	80	$10.40	$832.00
Hollow Core Slab: 4HC10	33	2.5	82.5	$10.40	$858.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab: 4HC8	30	4	120	$10.35	$1,242.00
Hollow Core Slab:	30	4	120	$10.35	$1,242.00

4HC8					
Hollow Core Slab: 4HC8	22	4	88	$10.35	$910.80
Hollow Core Slab: 4HC8	22	4	88	$10.35	$910.80
Hollow Core Slab: 4HC8	22	4	88	$10.35	$910.80
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	9	4	36	$10.35	$372.60
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab:	32	4	128	$10.35	$1,324.80

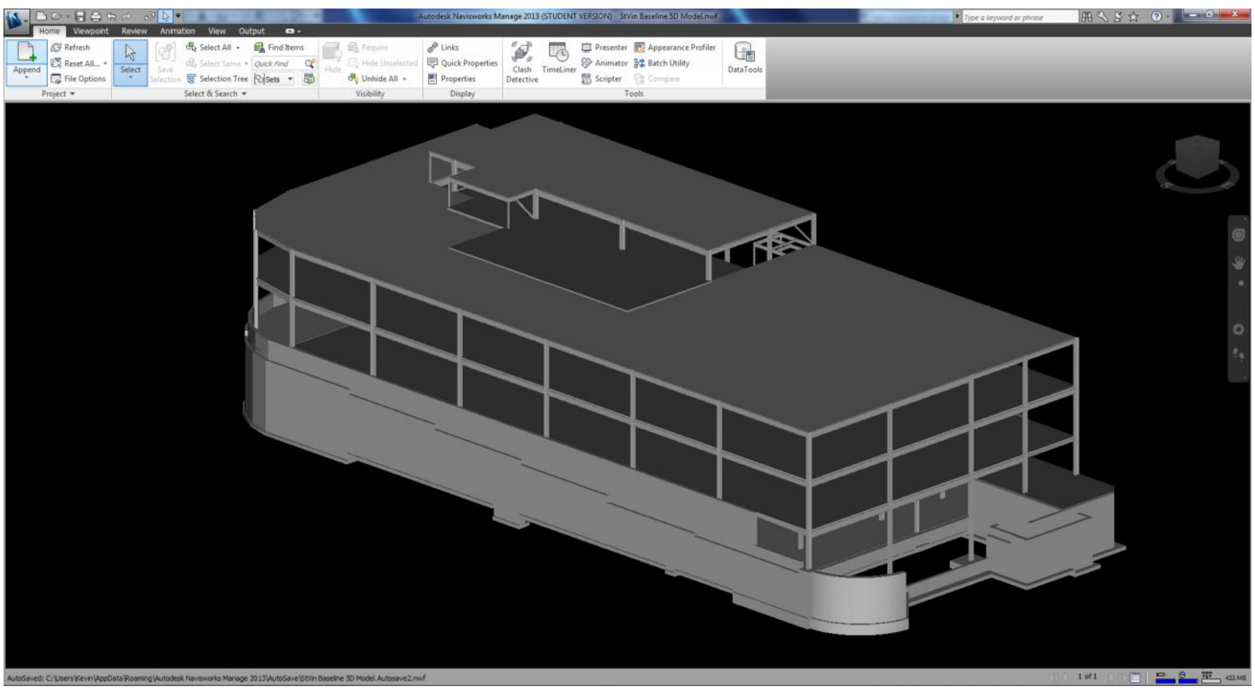
4HC8					
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	32	4	128	$10.35	$1,324.80
Hollow Core Slab: 4HC8	30	2.5	75	$10.35	$776.25
Hollow Core Slab: 4HC8	32	2.5	80	$10.35	$828.00
Hollow Core Slab: 4HC8	32	2.5	80	$10.35	$828.00
Hollow Core Slab: 4HC8	9	2.5	22.5	$10.35	$232.88
				Total Cost	$646,693.35

2 in Concrete Cover	Area (sq. ft.)	thickness (ft.)	Total CY	Cost per SF	
Mezzanine Level	2312	0.17	385.33	$2.47	$5,710.64
2nd Floor	17735	0.17	2955.83	$2.47	$43,805.45
3rd Floor	16088	0.17	2681.33	$2.47	$39,737.36
Roof	2046	0.17	341.00	$2.47	$5,053.62
Mechanical Roof	4220	0.17	703.33	$2.47	$10,423.40
			7066.83	Total Cost	$104,730.47
				Total Concrete Costs	$751,423.82

Appendix S: Guide to Create 5D Model

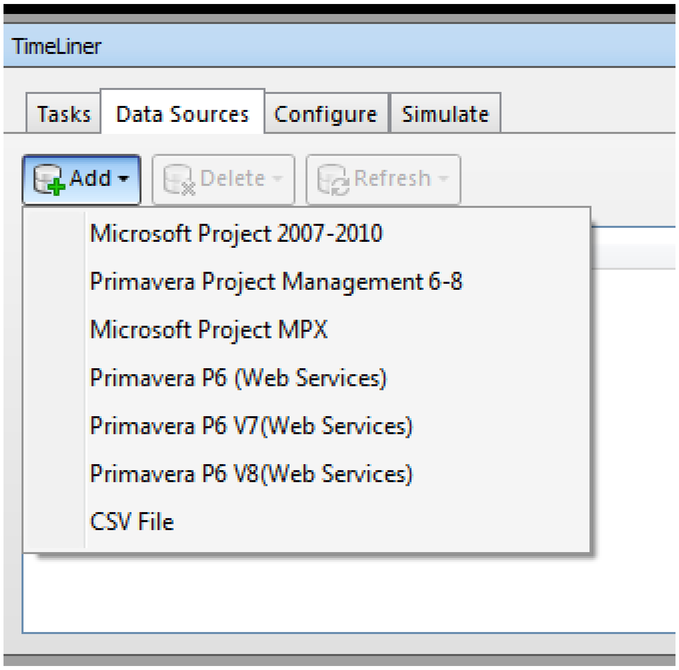


1. Once a *Revit* model is ready, select **File>Export>NWC** (right). This creates a *Navisworks* cache file, which is the basis to start a 5D model.
2. Following the export, open the new file in *Navisworks.* Barring any errors in the export process, the 3D model should look similar to structure made in *Revit*, seen

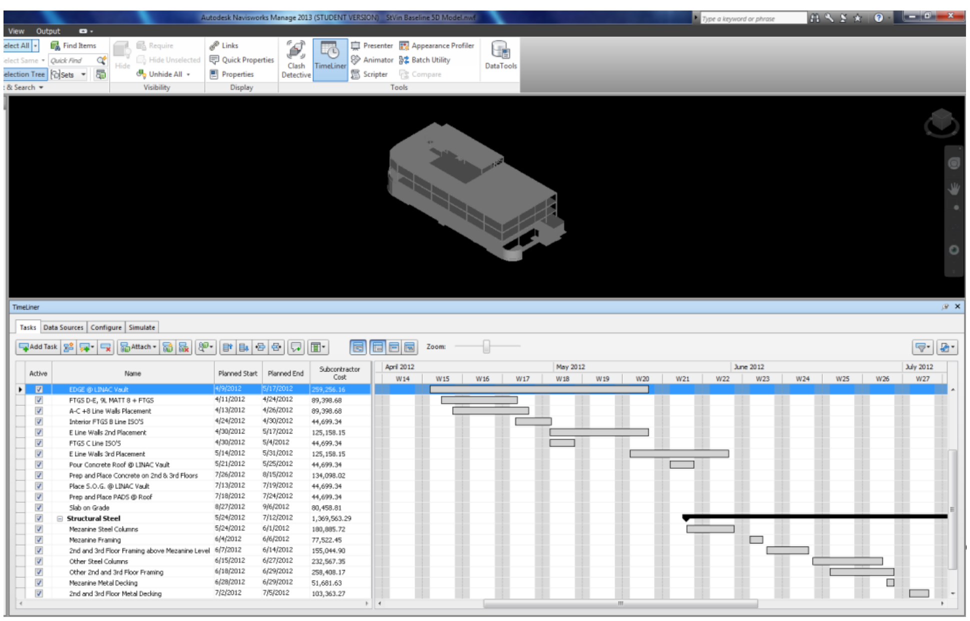


below.

3. If the model is ready for cost and schedule integration, open the **TimeLiner** toolbox on the **Home** ribbon. Once **TimeLiner** is open, cost and schedule information can be added to the model, or if an external application was used for scheduling, it can be imported. Using the **Data Sources** tab, choose from any of the available file formats, shown to the left. (For the St. Vincent case, the group exported the *Primavera* file to *Microsoft Project*, and imported the *Microsoft Project* file in *Navisworks*. This was to avoid multiple errors that occurred when trying to directly import the *Primavera* file.)

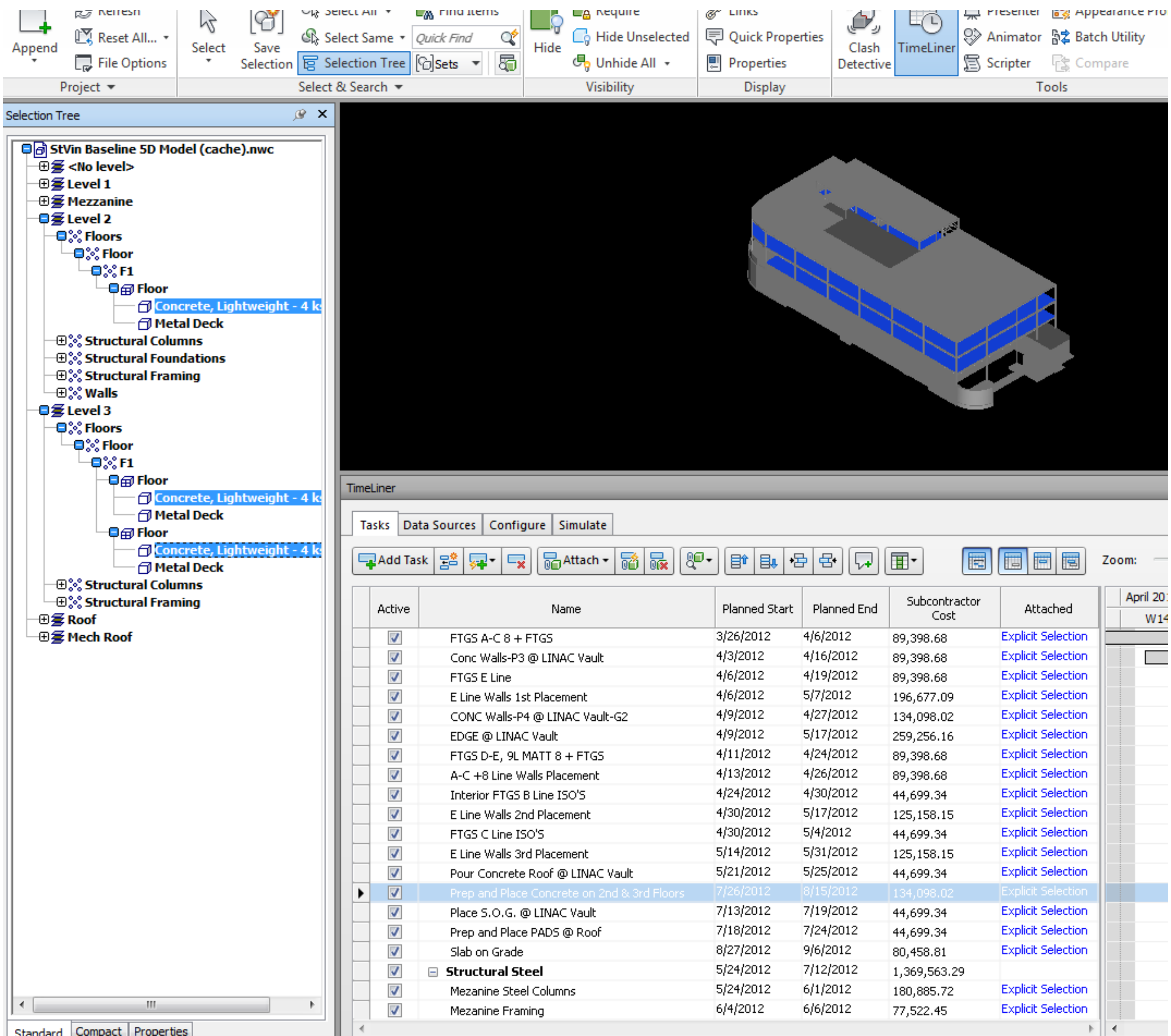


4. The data from scheduling software should be shown in the Tasks tab and include all the information that was to be imported. The interface should show start and end dates, along with any costs associated with each task, on the right side of the



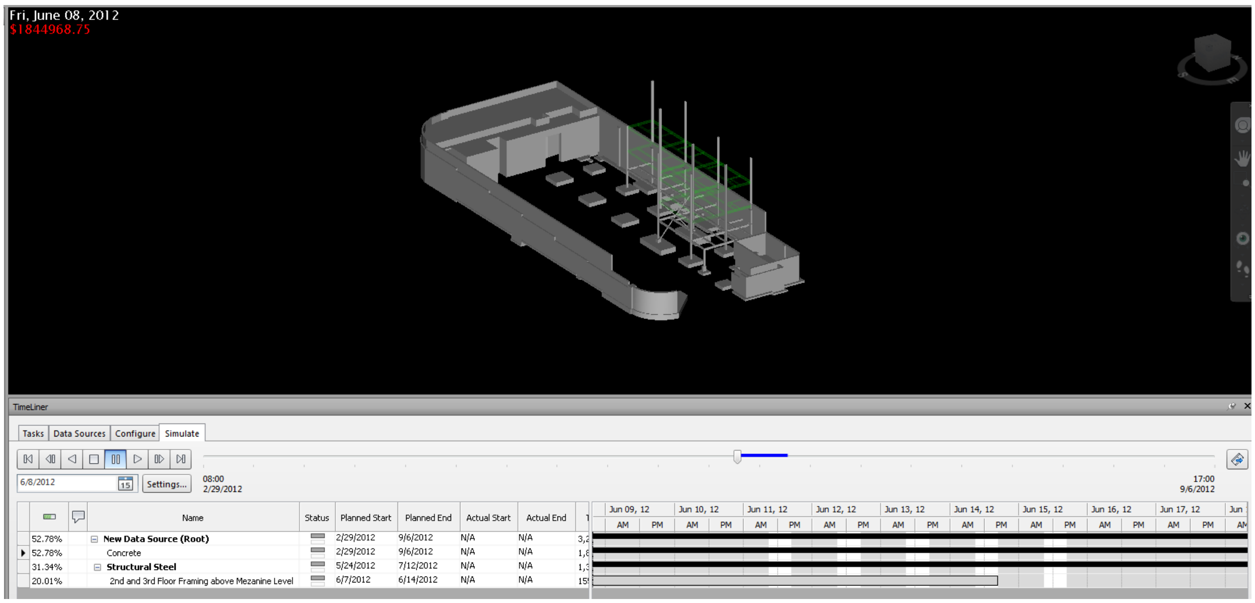
window, and a bar chart of activities on the left side of the screen (see right).

5. After the activities are confirmed to be correct, it is time to assign groups of elements to different tasks so that the 5D model can show the progression of construction. There are several methods to add elements to activities, with the simplest being “drag-and-drop.” This can be done from both the actual model and the selection tree. The figure below shows the level two and level three concrete slabs selected and ready to be dragged to

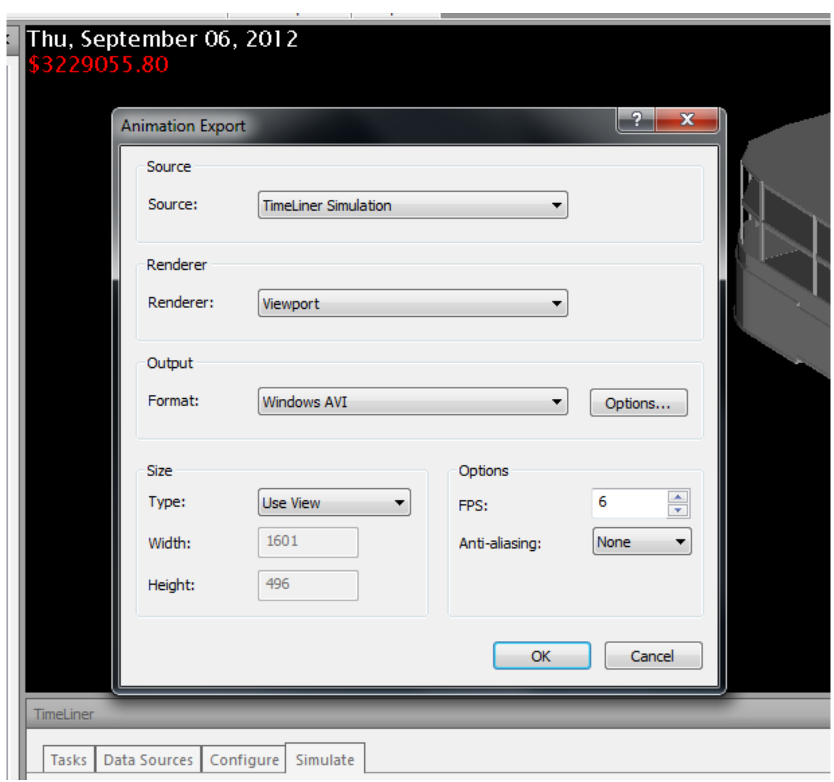


the "Prep and Place Concrete on 2nd and 3rd Floors" activity in the **TimeLiner**.

6. Once all the elements have been assigned to tasks, select the **Simulate** tab to review the 5D model (below). Use **Settings…** to adjust the speed of the simulation, the starting and ending points, the data displayed on the simulation, and various other options.

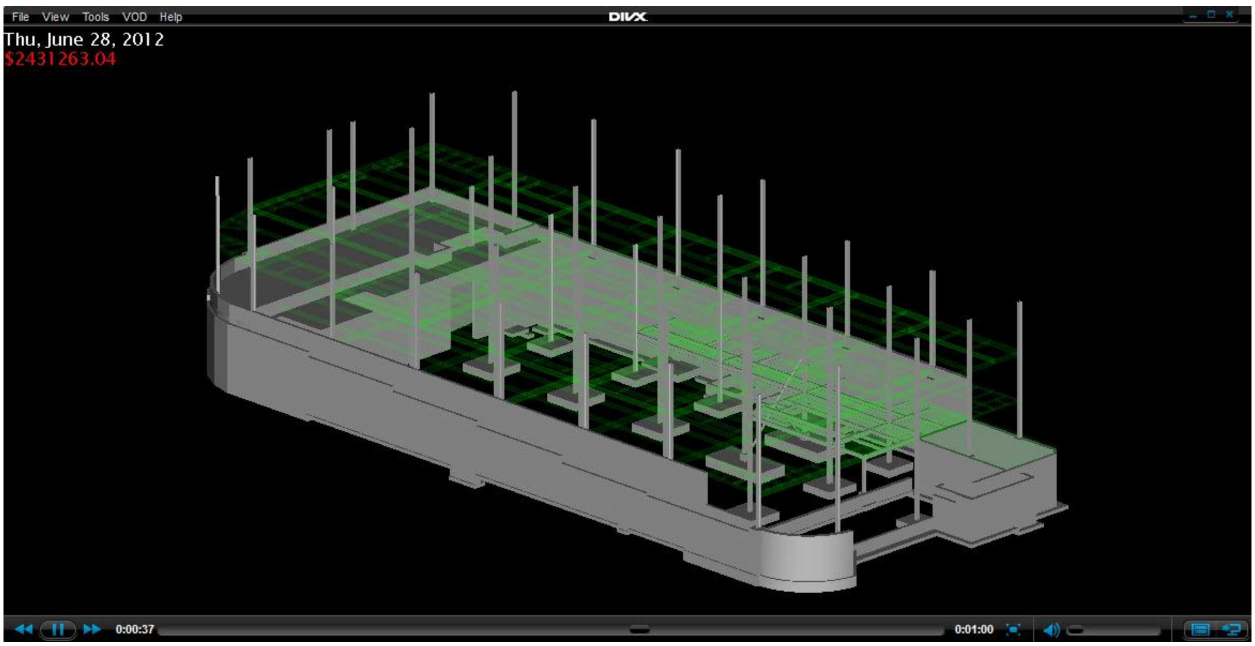


7. To finalize the 5D model, it can be exported as a video file for viewing in other applications. Under the **Animation ribbon**, use the **Record** tool to record the 5D simulation. Following the recording, choose **Export Animation**.



In the pop-up window (right), select the settings that best suit the project and the desired output.

8. The figure below shows a screenshot of the St. Vincent case 5D video. In the upper left corner, the date and cost at that point of the simulation is shown.



Appendix T: Folder Containing Software Files

File Folder and Name	**File Type**
3.0 Baseline	
StVin Baseline Model	*Revit*
StVin Baseline Model (simple foundation)	*Revit*
Simple Structure Model	*Revit*
Simple Structure Analysis	*Robot*
StVin Baseline Analysis	*Robot*
StVin Baseline Schedule	*Primavera*
4.0 Open-Web Bar Joist	
StVin Bar Joist Model	*Revit*
StVin Bar Joist Analysis	*Robot*
StVin Bar Joist R1 Model	*Revit*
StVin Bar Joist R1 Analysis	*Robot*
StVin Baseline Schedule	*Primavera*
5.0 Precast Planks	
StVin Baseline Model (rectangular foundation)	*Revit*
StVin Precast Planks Model	*Revit*
StVin Precast Planks Analysis	*Robot*
StVin Precast Planks Schedule	*Primavera*
7.0 Five-Dimensional Models	
StVin Baseline 5D Model (cache)	*Navisworks* cache
StVin Baseline 5D Model	*Navisworks*
StVin Baseline 5D Model-Video	AVI Video

Appendix U: Email Response from: Nesil Normile (PCI)

1. What is the average lead time for hollow core precast planks?
Typical lead times: 4 weeks shop drawings + 4 weeks production after the receipt of approved shop drawings Do precast floor systems have any advantages versus steel decking with cast-in-place concrete?
Yes. Among many the followings are couple reasons why project teams choose hc plank:

- Quality:

  - Factory manufactured – controlled environment with high QC standards per PCI vs job site concrete quality depends on "different concrete mix supplier, transportation of the ready mix concrete, quality of the crews, weather conditions, job site conditions etc".

  - Installation is by PCI qualified/certified crews

- Speed

  - 3,500 PSI Concrete in One Day

  - All year around manufacturing and installation

  - Install 8,000-10,000 sf/day (does not stop with weather conditions, cold, wind etc)

  - Manufacturing capacity 12,000sf/day from Oldcastle Selkirk plant

- Flex Design

  - With only 8" thick hollowcore plank, we can span up to 30' (without any need of mid support structural components). Having less vertical components (columns, walls etc) creates larger open spaces. Also this is achieved by thinner sections than CIP. Saves on building height and exterior surface or allows to have an additional floor.

  - Compatible with many structural different materials (CIP, masonry, steel, metal stud, precast etc).

- Fire Ratings:

  - No need to additional fire proofing.

  - Hollowcore plank has 1-1/2 hr fire rating without any topping, 2hr fire rating with ½" gypcrete and up to 4hr fire rating with concrete topping.

- Sound Ratings

  - Hollowcore plank with no additional material has 52-54 STC rating.

- Creates sturdy, quiet places.

- Sustainability:

- Reduced support and footings

- Reduced exterior material

- Reduced on site work & waste

- Recycled & regional materials

- No requirement for temporary formwork

- Reduced energy use (enclosed plant & natural curing)

- Concrete waste recycled

- Less material ==> less energy ==> lighter ==> less fuel to transport

2. What would be an average erection time for setting the precast planks?
Typically the crews can install 8,000-10,000sf hollowcore plank / day (aprx 40 piece/day of 8'-0" wide or aprx 80 pieces/day of 4'-0" wide)

3. What are the average costs associated with precast planks? Is there an average price per square foot?
This really depends on type of the project, footprint, the thickness of the plank, the location of the project and the bearing structure type. I'll be more than happy to assist them if they have more info on the project.

4. In our project, we use Autodesk Revit and Robot to model and analyze each structure. As we try and create the hollow core precast plank model, we are realizing that this kind of precast floor system does not exist in Revit (to our knowing). Do you or your company have any experience with softwares like these? If so, do you know any methods to model hollow core planks on a steel frame in Revit and complete a structural analysis on this kind of floor system in Robot?
As far as revit we do not have it modeled. We do have CAD details on my website you can down load for free. Look under technical resources then hollowcore.

Appendix V: Email Response from: Joe Carrara (J.P. Carrara and Sons, Inc.)

1. What is the average lead time for hollow core precast planks? Do precast floor systems have any advantages versus steel decking with cast-in-place concrete? This question is obviously dependent upon how busy the market place is. Under typical market conditions most hollow core plank producers will need about 4 to 6 weeks for shop drawing development & approvals and about 10 weeks for fabrication for a job of this size. Could be longer pending how busy the fabricator is.

There are several advantages of precast concrete floor and roof plank compared to cip concrete decks such as speed of construction, the fact that the plank are prestressed and are in compression for the most part and therefore will not exhibit cracking as cip concrete typically does and the prestressing allows for much better depth/span ratios allowing thin sections to span much farther than cip deck thus requiring fewer steel columns and beams and lowering the floor-to-floor heights which saves on your wall systems cost. You can also utilize the plank voids to run utility lines within the plank and out of sight.

2. What would be an average erection time for setting the precast planks? A typical erector can erect approximately 6,000 to 9,000 sf/day pending on the complexity of the structure.

3. What are the average costs associated with precast planks? Is there an average price per square foot? Cost is dependent on the required plank thickness. 8" thick plank is the most common and goes for approximately $7.50 to $10.50/sf design, fabricated and delivered to the jobsite pending layout efficiency and complexity. Installation of the plank including welding and grouting runs approx. $2.50 to $3.50/sf.

4. In our project, we use Autodesk Revit and Robot to model and analyze each structure. As we try and create the hollow core precast plank model, we are realizing that this kind of precast floor system does not exist in Revit (to our knowing). Do you or your company have any experience with softwares like these? If so, do you know any methods to model hollow core planks on a steel frame in Revit and complete a structural analysis on this kind of floor system in Robot? Unfortunately we do not have this capability in our office at this time.